UNIVERSITY OF BIRMINGHAM | DEPARTMENT OF ECONOMICS

A review of TAG A2.3 employment parameters: labour supply elasticity and labour tax wedges

Report to the **Department for Transport**
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By
Marco G. Ercolani[*†]
Joseph P. Bromfield[*]
Sheikh Selim[**]

With the research assistance of:
Teck Thye Chua[***]
Kien Son Nguyen[***]

[*] Department of Economics, University of Birmingham, England
[**] Department of Economics, University of Birmingham, Dubai
[***] PhD Economics candidate, University of Birmingham, England

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Executive Summary

- This project is tasked with reviewing four core parameters used by the Department for Transport, in its Transport Analysis Guidance (TAG) A2.3, to appraise the Employment Effects of proposed transport infrastructure investments.

- The first of these parameters, the labour supply elasticity with respect to wage changes (ε^{LS}), is currently calibrated at 10%. This elasticity is ratio of the proportionate change in labour supply to the proportionate change in wage that caused it. An elementary averaging of the most recent research for the UK suggests it should be approximately 22%, and within a 14% to 43% range.

- Considering the age of existing research and the impacts of the Covid-19 pandemic, an empirical study is recommended to estimate both extensive and intensive labour supply elasticities using population-representative, microeconomic UK data.

- The other three parameters under review are the average tax wedges on the earnings of: new workers (τ_1=30%), new workers including savings by not paying unemployment benefits (τ_2=40%), and existing workers moving to more or less productive jobs (M2MLPJ, τ_3=30%).

- The 30% tax wedges for new and existing workers (τ_1, τ_3) serve as effective working values. However, they should be reviewed once UK price inflation returns to the Bank of England's 2% target, at which point the alignment of income tax and National Insurance thresholds with real earnings is expected to have stabilised.

- The 40% tax wedge (τ_2) appears reasonable, but it would benefit from a study to confirm whether the non-payment of out-of-work benefits to newly employed workers results in approximately a 10% saving for the Exchequer.

- This review begins with a commentary on the TAG A2.3 documentation, elements of which the Department for Transport could use in documentation updates. This is followed by the main body of the review. It concludes with a simple calibration exercise to gauge the implications of modifying the four parameters under review.

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Contribution:

- Marco G. Ercolani contributed to all sections.
- Joseph P. Bromfield was the main contributor to Section 3 on labour supply elasticities with the research assistance of Teck Thye Chua
- Sheikh T. Selim was the main contributor to Section 4 on tax wedges with the research assistance of Kien Son Nguyen

1 Introduction

Key points: This project is tasked with reviewing the values of four core parameters used by the Department for Transport (DfT) to appraise the *Employment Effects* of transport infrastructure investments. These four parameters include the *labour supply elasticity* and three *tax wedges*, see section 1.2 for definitions. These Employment Effects appraisals are based on the Transport Analysis Guidance (TAG) A2.3 outlined in DfT (2016, 2019), and are in addition to the core cost-benefit analyses outlined in other DfT TAG documents.

These Employment Effects can be categorised according to whether they lead to a change in the number employed (*Labour Supply Impacts*) or movements to more or less productive jobs (*M2MLPJ*) among those already employed. Both can also be sub-divided according to whether they lead to changes in Gross Domestic Product (GDP) or changes in net tax revenues to the Exchequer (wider impacts). Combining these two categorizations results in four measures, as shown below.

A larger labour supply elasticity leads to greater increases in both employment and GDP, as a result of travel time and travel cost savings. It also leads to greater '*wider benefits*' from increased labour tax revenues. The effect of changes in tax rates is ambiguous. Higher tax rates reduce the gains from travel time and travel cost savings, leading to lower employment gains and thus smaller related GDP gains. However, higher tax rates also lead to greater '*wider benefits*' due to greater revenues to the Exchequer.

1.1 Basic technicalities

Here is a preliminary overview of the TAG A2.3 parameters under analysis, complete with their presently used values:

- $\varepsilon^{LS} = 10\%$: The labour supply elasticity, defined as the proportionate change in employment divided by the proportionate change in wages that caused it.
- $\tau_1 = 30\%$: The average tax wedge on the earnings of new workers, including: income tax and NI contributions.[1]
- $\tau_2 = 40\%$: The average tax wedge on the change in labour supply, including: income tax, NI contributions, and savings from no longer paying out-of-work benefits to those who are now in work.
- $\tau_3 = 30\%$: The average tax wedge on the earnings of existing workers who switch jobs, including: income tax, NI contributions and corporation tax. τ_3 is used in DfT (2014) and in the Wider Impacts of Transport Appraisal (WITA) simulation software but is replaced with τ_1 in DfT (2019, 2016).

[1] DfT (2019, page 10, footnote 2) indicates the 30% value is based on "average tax revenue from income tax, NICs, corporation tax and mixed income."

It is useful to acquaint oneself with the terminology used throughout TAG A2.3. The term *Employment Effects* pertains to four distinct additional effects particular to TAG A2.3. One way of categorising Employment Effects is based on these two sources:

- *Labour supply impacts* resulting from the change in the number of workers.[2]
- *Movements to more/less productive jobs (M2MLPJ)* resulting from job switches among those who remain employed.[3]

Employment effects can also be categorised as one of two outcomes:

- *GDP impacts*: These are the net changes to GDP.
- *Wider impacts*: These are the revenues accruing to the Exchequer from both *GDP impacts*. The first of these also includes savings of not paying unemployment benefits to newly employed workers.

Table 1 is adapted from Table 4 in TAG A2.1 (DfT 2018) and illustrates where the four resulting TAG A2.3 employment effects (shaded in grey) fit among the various cost-benefit analyses of proposed alternative transport scenarios. Table 1.1 also lists where the four parameters under review appear in the modelling.

1.2 Report structure

This report follows the subsequent structure, designed to provide context before reviewing the four parameters, and then provide simulation results using suggested parameter values:

- Introduction
- A new explanation of TAG A2.3 modelling approach
- Literature review of labour supply elasticity
- Literature review of labour tax wedges
- Simulations using revised labour parameters
- Summary
- References
- Technical appendices

[2] In TAG A2.3, various assumptions underlie the *Labour Supply Impacts*: First, the impacts cannot be assumed and must be justified in the *Economics Narrative*. Changes are only assumed between employment and inactivity, while unemployment numbers are assumed constant, see Appendix A1.1. A perfectly elastic labour demand is also assumed, therefore, changes in labour do not affect wages.

[3] In TAG A2.3 the presence of this effect does not need to be justified to the same degree as the labour supply impact. However, it is subject to the constraint that the overall number of workers remains constant at a national level and the M2MLPJ needs to be based on a supplementary economic model.

Table 1.1: GDP effects and Welfare impacts in DfT TAGs

TAG	**Title and descriptions**	**GDP Impacts**	**Welfare Impacts**
A1.3	User benefits		
		Business User benefits	User benefits from business, commuting and leisure trips
A2.2	Induced Investment		
	Dependent Development	Additionality modelling required, see SEM M5.3	Land value uplift
	Output Change in Imperfectly Competitive Markets	10% of Business User benefits	10% of Business User benefits
A2.3	Employment Effects (and included parameters):		
	Labour Supply Impacts (LSI)	GDP changes. ε^{LS}, τ_1	Tax revenues: 40% of LSI GDP change. $\varepsilon^{LS}, \tau_1, \tau_2$
	Move to More/Less Productive Jobs (M2MLPJ)	GDP changes. *Excludes all four reviewed parameters*	Tax revenues: 30% of M2MLPJ GDP change. τ_3 (or τ_1)
A2.4	Productivity Impacts		
	Agglomeration Economies (inc. static and dynamic clustering)	Agglomeration Impacts	Agglomeration Impacts

2 A new explanation of the TAG A2.3 modelling approach

Key points: Given that the remit of this research project is to provide literature reviews of the labour supply elasticity parameter (ε^{LS}) and tax wedge parameters (τ_1, τ_2, τ_3), it is important to understand how these parameters fit within the TAG A2.3. To this end, equations 1 to 6 in TAG A2.3 used to model the *Employment Effects* of transport infrastructure investments are presented.

The description of TAG A2.3 parameters and equations in this section borrows heavily from DfT (2019, 2016, 2014) and DfT 2018, and suggestions are made for future revisions of TAG A2.3. While offering a fresh perspective on these sophisticated equations, it retains most of the terminology, notation and equation numbering. Minimal changes to the equations and notation are suggested given they are used in other DfT guidance and in the Wider Impacts of Transport Appraisal (WITA) simulation software.

2.1 Summary of the time-invariant and area-invariant parameters

Table 2.1 offers a detailed overview for the four parameters under review and the productivity parameter η. It is adapted and expanded from the worksheet "Labour Market Impacts" in the WITA spreadsheet "tag-wider-impacts-dataset-July-2021.xlsx".[4] The second column in Table 2.1 lists the presently used values for these parameters, while the final column lists the equations in which each parameter appears. None of the listed parameters are present in equation 5, however, both equation 5 and parameter τ_3 (or τ_1) appear in equation 6.

The parameters in Table 2.1 do not vary across time and geographical areas. However, other parameters or variables in equations 1 to 6 can vary across future years (f) and/or across geographical areas (i, j). These areas can refer to workers' home districts (i) and/or workplace districts (j). For areas, TAG 2.3 uses the 380 local authority districts (LAD) in England, Scotland and Wales.

[4] Source: https://www.gov.uk/government/publications/tag-economic-impacts-worksheets , accessed 8/8/2023.

Table 2.1: Time and area invariant TAG 2.3 parameters

Var.	Value	Description	Source	Appears in TAG 2.3 equations
ε^{LS}	0.10	Labour supply elasticity with respect to net financial returns from working	Estimate based on DWP calculations and wider literature review.	2, 3, 4
η	0.69	Productivity parameter to capture the lower productivity of new labour-force entrants	Based on evidence from Gregg, Johnson and Reed (1999, Table 3.6).	3, 4
τ_1	0.30	Average tax wedge on earnings of new workers.	Based on average tax revenue from income tax (22% income tax rate assumed), NICs, corporation tax,[5] and mixed income. For converting gross to net wages, only the tax on existing jobs is considered.	2, 3, 4
τ_2	0.40	Average tax wedge on new workers, including savings on not paying unemployment benefits.	Estimated tax-take of GDP changes from increased labour market participation. Tax incorporates average income effects of new workers, operating surplus, and foregone unemployment benefits.[6]	4
τ_3	0.30	Average tax wedge on earnings of existing workers M2MLPJ.	Estimated tax-take of GDP changes from existing workers becoming more, or less, productive and hence attracting a marginal income tax as well as an increased operating surplus. In DfT (2019, section 3.3.8) this is described as including income tax, national NICs and corporation tax.	6

Notes: There is ambiguity in relation to whether τ_1 or τ_3 is used in equation 6. In DfT (2016, 2019, eq. 6) τ_1=0.30 is used, while in WITA software guidance and DfT (2014, eq. 4.5a) τ_3=0.30 is used.
Most of the six TAG 2.3 (DfT 2016, 2019) equations previously appeared in DfT (2014) TAG 2.1 with different reference numbers: equation 1 was 4.3, equation 2 did not appear, equation 3 was 4.1, equation 5 was 4.4, and equations 4 and 6 were combined into equation 4.5a.

[5] OECD (2023c, page 14) states that their tax measures, and therefore tax wedges too, do not include corporation tax: "… any income tax that might be due on non-wage income and other kinds of taxes – e.g. corporate income tax, net wealth tax and consumption taxes – are not taken into account." In Section 4 we contrast what seems to be the microeconomics-based approach of the OECD to the macroeconomics-based one of the DfT.

[6] As discussed in Section 4 on taxation, we feel that either 'unemployment benefits' should be replaced with 'out of work benefits excluding unemployment benefits' in the definition of τ_2, or the analysis should allow for the number unemployed to change as a result of the alternative transport scenario.

2.2 The six TAG A2.3 equations for GDP changes and Wider Benefits

The six TAG A2.3 equations are used to compute *non-welfare measures* of future changes when switching from an existing *Baseline* transport scenario (B)[7] to a proposed *Alternative* transport scenario (A)[8] with a change to the transport infrastructure. As already seen in Table 1.1, categorising these six equations helps understand the functions they serve.

The non-welfare measures in TAG A2.3 are in contrast to *welfare measures* based on *cost-benefit analyses* in line with HM Treasury (2022) Green Book guidance used to determine *value for money*. As in TAG A2.1 (DfT 2014), private surpluses are assumed to capture all *welfare effects* unless: significant feedback effects occur or market distortions or failures are affected by the proposed alternative transport scenario.

Equations 3 to 6 can be sub-divided according to whether they model the change in the *number* of workers or model *existing* workers changing jobs:

- *Labour supply impacts* are modelled using equations 3 and 4 in Section 3.2 of TAG A2.3, and refer to the change in the *number* of people employed. Labour supply impacts cannot be assumed, and their inclusion must be based on the existence of feedback effects or changes to market distortions.
- The impact of existing workers *moving to more/less productive jobs* (M2MLPJ) is modelled using equations 5 and 6 in Section 3.3 of TAG 2.3. M2MLPJ can be assumed to occur. In line with HM Treasury (2022) Green Book guidance, the total national number of workers must be kept constant in the modelling, unless supply side employment impacts can be shown to exist.

Alternatively, equations 3 to 6 can be sub-divided according to whether they lead to a direct change in GDP or *Wider Benefits* via net tax revenues to the Exchequer.

- Equations 3 and 5 model changes in GDP that accrue directly to the economy. They are measured as the change in net (post direct-tax) earnings.
- Equations 4 and 6 model the *Wider Benefits* that accrue to the general population via new revenues or savings to the Exchequer.

Equations 1 and 2 serve purely as underpinnings to equations 3 and 4:

- Equation 1 is used to quantify changes in generalised transport costs from switching from the baseline transport scenario to the alternative one, and underpins equation 2.

[7] Referred to as the *do minimum* scenario in the WITA software.
[8] Referred to as the *do something* scenario in the WITA software.

- Equation 2 is used to model changes in the number of people switching from *inactivity* in the labour market to *employment*, without transitioning through *unemployment*. Equation 2 underpins equation 3, and therefore equation 4.

2.3 Equations 1 & 2: changes between inactivity and employment

The change in the number of workers is estimated by using the 'generalised' average cost of commuting from equation 1 to determine its impact on the number of those employed, as shown in equation 2.

Equation 1 below is an initial building block used to compute the average daily round-trip generalised commuting costs between areas i (home) and areas j (workplace) under each transport scenario, either $S = A$ or $S = B$, based on transport modes m in forecast years f. 'Generalised' means that both the direct cost of commuting and the foregone work time are included in the calculation.

Equation 1 Average Round-trip Generalised Commuting Cost
$$G_{i,j}^{S,f} = \frac{\sum_m (g_{i,j}^{S,m,f} + g_{j,i}^{S,m,f}) T_{i,j}^{S,m,f}}{\sum_m T_{i,j}^{S,m,f}}, \quad \forall i, j, f, S$$
$G_{i,j}^{S,f}$ is the average round-trip generalised commuting cost, including all expenses and time.
S is either the alternative transport scenario A or the baseline scenario B.
$g_{i,j}^{S,m,f}$ are the general costs of commuting from i to j under scenario S in mode m for year f.
$g_{j,i}^{S,m,f}$ are the general commuting costs of returning from j to i under the same scenario S.
$T_{i,j}^{S,m,f}$ is the *annualised* number of commuting trips form i (home) to j (workplace). Notice, these are only in one direction. Values are annualised insofar as they account for non-work days, such as weekends, national holidays, personal holidays and non-return trips.

Equation 2 below is used to compute the employment impact of the alternative transport scenario A. In contrast to equation 2 in DfT (2019), in equation 2 below:

- ΔE^f replaces E^f to emphasise that this is a *change* in employment.
- The S superscript in $W_{i,j}^{S,f}$ can be omitted as it is redundant, given this value pertains to both scenarios.[9]

[9] In the WITA software guide (DfT 2018, page 78) the same variable is $DHTW_{IJ}^{1y}$ and could have the 1 omitted, where 1 represents the 'alternative scenario'. Better still, the WITA software guide could be rewritten so that all the variables and parameters match the notation in TAG A2.3. For instance, $DHTW_{IJ}^{y}$=$W_{i,j}^{f}$ is the same variable in each.

- Ω replaces $\Omega_j^{S,f}$ given this parameter is invariant across time f and employment area j. The S superscript too is redundant.
- ε^{LS} and $G_{i,j}^{B,f} - G_{i,j}^{A,f}$ are used instead of $-\varepsilon^{LS}$ and $G_{i,j}^{A,f} - G_{i,j}^{B,f}$. Though this changes nothing, it highlights that the labour supply elasticity has a positive effect on employment if average commuting costs decrease.
- To match equation 3, the right-most square bracket has been repositioned. Furthermore, square brackets and round parentheses have been swapped.

Equation 2 Labour Supply (Employment) Impact
$$\Delta E^f = \sum_i \left[\varepsilon^{LS} \left(\frac{\sum_j (G_{i,j}^{B,f} - G_{i,j}^{A,f}) W_{i,j}^f \Omega}{(1-\tau_1)\sum_j y_j^f W_{i,j}^f} \right) \sum_j W_{i,j}^f \right], \quad \forall f$$
ΔE^f are the national changes in employment in each forecast year f.
ε^{LS} is the labour supply elasticity, currently assumed to be 0.10.
$G_{i,j}^{A,f}$ and $G_{i,j}^{B,f}$ are the average round-trip costs estimated in equation (1).
$W_{i,j}^f$ are the numbers of workers living in area i, employed in area j in the baseline scenario.
Ω is the average number of round-trip commuting journeys per worker. In future revisions this might be replaced with Ω_j^f if its value varies across employment area j and forecast year f.
τ_1 is the tax wedge required to convert gross earnings (y_j^f) into net earnings for new workers. It is based on average tax revenue from income tax, NI contributions, corporation tax and mixed income.
y_j^f are average gross annual pay rates for workers employed in area j. These values are available in the "tag-wider-impacts-dataset-July-2021.xlsx" workbook, in worksheet "Avg. workplace-based earnings".

Though equation 2 is for new workers, the same tax wedge τ_1 is used for existing workers in equation 6, thus making no judgement on differences in the composition of these two groups. However, if the tax wedge for new workers were assumed to be smaller than for existing workers (e.g. $\tau_{nw} < \tau_{ew}$)[10], the employment and GDP impacts in equations 2 and 3 would be smaller for the same improvements in journey costs. This is because the same travel benefits would be a smaller proportion of larger post-tax earnings.

To understand equation 2, consider the numerator and denominator in the core fraction before it is summed across the home districts i:

[10] For instance, because they experienced substantially lower earnings than existing workers, alongside facing a markedly progressive tax system

- $\sum_j (G_{i,j}^{B,f} - G_{i,j}^{A,f}) W_{i,j}^f \Omega_j^f$ is an estimate of the annual generalised travel cost savings for all workers employed in work areas j brought about by the alternative scenario A.
- $(1 - \tau_1) \sum_j (y_j^r W_{i,j}^{S,f})$ is an estimate of the net earnings for all workers employed in work areas j.

The ratio of these two is therefore the proportionate savings brought about by transport scenario A, and multiplying this by the labour supply elasticity ε^{LS} gives the proportionate increase in the number of workers. Multiplying this proportionate increase by the number of workers in each work area $\sum_j W_{i,j}^f$ gives each work area change in the number of workers. Finally, summing across workers commuting from areas i gives the national change in the number employed in each forecast year f. Appendix A1.2 discusses differences in how equation (2) is specified in DfT (2016) versus DfT (2019). DfT (2019, paragraph 3.2.5) provides a useful summary for equations 1 and 2:[11]

> Equations 1 estimate generalised travel costs and commuting costs for journeys between the relevant areas for different modes. Equation 2 estimates the total labour supply impact across the areas where costs of travel are expected to change as a result of the transport scheme. The estimation of a positive labour supply impact anticipates the expected increase in jobs from people entering work who would otherwise be inactive due to high commuting costs.

DfT (2019, paragraph 3.2.6) lists the three assumptions that underlie the labour supply impacts which can be summarised as:

- "First, … demand for labour is perfectly elastic … when estimating labour supply impacts; … employers are willing and able to absorb an increase in the supply of labour at the prevailing wage rate."
- "Second, … people make decisions about whether to work on the basis of their net wage … [that] accounts for employment taxes, such as income tax and national insurance contributions."
- "Third, … reductions in the generalised cost of commuting increase the effective net wage and vice versa."

2.4 Equations 3 & 4: direct and wider impacts of employment changes

Equation 3 is used to estimate the impact on GDP of changing the employment level as a consequence of the alternative transport scenario A. Equation 3 is similar to equation 2, with the simple addition of gross median wages ($m_j^f = \eta y_j^f$) for workers

[11] DfT (2016) paragraph 3.2.5 includes typos in equation numbers, perhaps resulting from a different equation arrangement in a previous TAG.

entering the labour market in each labour market zone j. The start of paragraph 3.2.7 of DfT (2019) summarises equation 3 as: "The valuation of the labour supply impacts resulting from a scheme can be calculated in terms of GDP impacts from equation 3 below."[12] Equation 3 below is equivalent to equation 3 in DfT (2019) with ΔGDP^f replacing GDP^f to emphasise that this is a *change* in GDP, and ηy_j^f replacing m_j^f.

Equation 3 GDP labour supply impact (LSI)
$$\Delta GDP_{LSI}^f = \sum_i \left[\varepsilon^{LS} \left(\frac{\sum_j (G_{i,j}^{B,f} - G_{i,j}^{A,f}) W_{i,j}^f \Omega}{(1-\tau_1)\sum_j y_j^f W_{i,j}^f} \right) \sum_j \underbrace{\eta y_j^f}_{=m_j^f} W_{i,j}^f \right], \quad \forall f$$
ΔGDP_{LSI}^f are future (f) changes in GDP resulting from Labour Supply Impact employment changes.
$m_j^f = \eta y_f^f$ are the gross median wages of workers entering each labour market j.
$\eta = 0.69$ is a parameter capturing the lower productivity, and therefore lower wages, of marginal workers.
y_j^f is the average gross annual pay rates for those employed in area j, already defined in equation 2.

Equation 4 is used to estimate the *wider impacts* of the GDP change estimated by equation 3. These wider impacts are measured as the increase in tax revenues plus savings brought about by not paying out-of-work subsidies to those who are newly employed. These out-of-work subsidies could be taken to exclude unemployment benefit and include other benefits,[13] given that the TAG suggests the number of unemployed[14] is steady and determined by general equilibrium conditions. However, the mechanism could be more nuanced insofar as the level of unemployment might be maintained constant by balancing the flow of people transitioning from 'inactivity' to unemployment with those moving from unemployment into employment.[15]

The savings from not paying subsidies are the reason why the tax wedge parameter ($\tau_2 = 0.40$) for revenues to exchequer is larger than the tax wedge parameter ($\tau_1 = 0.30$) on workers. DfT (2019, paragraph 3.2.7) nicely summarises these wider welfare impacts:

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[12] In DfT (2016, paragraph 3.2.7) equations 3 and 4 are mislabelled as equations 4 and 5.

[13] Out-of-work benefits include Universal Credit which has incorporated other benefits such as Income Support and Housing Benefits. Other benefits include Council Tax Reduction and Support for Mortgage Interest.

[14] Economic theories such as the Natural Rate of Unemployment or Non-Accelerating Inflation Rate of Unemployment (NAIRU) are typically based on rates of unemployment rather than levels.

[15] Considering the numerous flow mechanism available for maintaining a steady unemployment rate, there may be no unique way of formulating this.

> The welfare impacts over and above user benefits are equivalent to the benefits to the exchequer. These are the tax revenues resulting from labour supply impacts and can be estimated as 40% of the resultant change in GDP. This tax revenue impact is calculated below in equation 4. This reflects both the increase in tax revenue (income tax, national insurance contributions and corporation tax) and the reduction in out of work subsidies.

In equation 4 the wider impacts are simply the GDP change multiplied by the tax wedge for new workers.[16] DfT (2019, section 3.2.8) specifies that "The tax revenue is associated with a welfare change because the presence of taxation distorts the labour and capital markets". Then reference is made to OECD (2010) in DfT (2019, footnote 3).

Equation 4 Wider Labour Supply Impacts
$WI_{LSI}^{f} = \tau_2 \Delta GDP_{LSI}^{f}, \quad \forall f$
WI_{LSI}^{f} are the welfare changes associated with labour supply impacts in each forecast year f. This replaces $WI2^{f}$ in TAG A2.3 to clarify the notation.
τ_2 is the time-invariant tax wedge on the labour supply impact of new workers moving out of inactivity. Currently estimated to be equal to 40%, it incorporates average income taxes on new workers (including NICs), operating surplus and lost unemployment benefits.

DfT (2019, paragraph 3.2.9) states four assumptions that underlie the valuing of labour supply impacts:

- "First, in accordance with HM Treasury Green Book guidance, perfect competition and full employment are assumed. … firms will employ additional workers until the point where the revenue increase from the marginal worker's output is equal to the wage rate. In other words, the change in GDP as a result of a labour supply impact is equal to workers' incomes."
- "Second, the productivity of workers on the margin of the labour force is lower than that of the average worker. This is reflected in equation 3 by the adjustment … parameter η."
- "Third, we do not value the private benefits of those entering employment and their employers … Those entering employment, and their employers, are implicitly assigned no private benefits. … This assumption also implies that the

[16] In DfT (2019, eq. 4) two typographical errors mean it is miss-specified as $WI2^{f} = \tau_1 GDP^{A,f}$ and should have been specified as $WI2^{f} = \tau_2 GDP^{f}$.

impacts of these new transport users do not significantly impact existing transport users …. This method is appropriate where is can be demonstrated that associated land use change is not significant. Where significant numbers of people are likely to be entering employment and there is an associated land use change, this should be identified in the Economic Narrative and an appropriate method should be identified … .”

- “Fourth, the welfare change associated with labour supply impacts is equal to the change in tax revenue.”

Partial derivatives can be used to summarise the effect of changing the labour supply elasticity parameter (ε^{LS}) and the two tax wedges (τ_1, τ_2):

- $\frac{\partial \Delta GDP^f_{LSI}}{\partial \varepsilon^{LS}} > 0$, thus, a larger labour supply elasticity leads to greater GDP gains from transport investments that decrease the generalised commuting costs.
- $\frac{\partial \Delta GDP^f_{LSI}}{\partial \tau_1} < 0$, thus, a larger tax wedge leads to smaller GDP gains from transport investments that decrease the generalised costs of commuting.

The partial derivative for the wider impacts with respect to the tax wedge τ_2 is more complex because it can be thought of being made of two components $\tau_2 = \tau_1 + \tau_B$, where the second component τ_B is the rate for out-of-work benefits. Substituting equation 3 into equation 4 and re-arranging results in Equation 4alt:

Equation 4alt, Alternative Wider Labour Supply Impacts
(splitting the tax wedge τ_2 into $\tau_1 + \tau_B$)

$$WI^f_{LSI} = \frac{\tau_1 + \tau_B}{1-\tau_1} \sum_i \left[\varepsilon^{LS} \left(\frac{\sum_j (G^{B,f}_{i,j} - G^{A,f}_{i,j}) W^f_{i,j} \Omega}{\sum_j y^f_j W^f_{i,j}} \right) \underbrace{\sum_j \eta y^f_j W^f_{i,j}}_{=m^f_j} \right]$$

τ_B is the out-of-work benefit rate, currently assumed to be 0.10 if one assumes that $\tau_2 = \tau_1 + \tau_B$ and use current set parameters ($\tau_2 = 0.40, \tau_1 = 0.30$).

Thus, the partial derivate of WI^f_{LSI} with respect to τ_2 can be specified in two parts. Firstly, solving for the partial derivative with respect to τ_1 is complicated by its direct presence in equation 4 and its indirect presence via equation 3. Secondly, solving for the partial derivative with respect to τ_B is relatively straightforward.

- $\frac{\partial WI^f_{LSI}}{\partial \tau_1} = \frac{1+\tau_B}{(1-\tau_1)^2} \sum_i [\dots] > 0$, thus, a larger tax wedge on new workers τ_1 leads to greater *wider impact* gains from beneficial transport investments.
- $\frac{\partial WI^f_{LSI}}{\partial \tau_B} > 0$, thus, a larger tax wedge τ_B related to out-of-work benefits leads to greater *wider impact* gains from beneficial transport investments.

2.5 Equations 5 & 6: direct and wider impacts of M2MLPJ

Equations 5 and 6 capture the direct and wider GDP impacts of existing workers moving to more/less productive jobs (M2MLPJ), while equations 1 to 4 captured the impacts of newly created jobs. Note that equation 5 is the only one of the six equations that does not include any of the four parameters (ε^{LS}, τ_1, τ_2, τ_3) under review in this study.

Equation 5 relies on separate economic modelling of how workers relocate to more or less productive jobs. In contrast, equation 6 is comparatively straightforward. DfT (2019, section 3.3.8) summarises valuing the M2MLPJ as:

> The valuation of the move to more/less productive jobs resulting from a scheme can be calculated in terms of GDP impacts from equation 5 below. The associated welfare change, which is additional to user benefits, is equivalent to the benefits to the exchequer. These are the tax revenues resulting from changes in productivity and can be estimated as 30% of the resultant change in GDP. This tax revenue impact is calculated below in equation 6. This reflects the increase in tax revenue (income tax, national insurance contributions and corporation tax).

DfT (2019, section 3.3.9) outlines the assumptions that underly the methodology for valuing the M2MLPJ:

- "First, the productivity change is a function of the average productivity differential of each area, gaining and shedding employment, from the national average." I.e. no national change in the level of employment.
- "Second, the output change associated with changes in productivity is valued by GDP per worker, which implies a change in the return to labour and capital. The geographical distribution of demand and supply of labour will be a function of profits and wages respectively. Thus, productivity changes [resulting from M2MLPJ are] associated with wage and profit changes. For this reason, the [M2MLPJ] are valued using GDP per worker."
- "Third, private benefits to employees and employers who are [M2MLPJ] are captured by the change in transport user benefits. However, the method for valuing [M2MLPJ] implies land use change."[17]

[17] The third item goes on to specify: "Where there are significant feedback effects from land use change the methodology to value user-benefits, rule of a half, breaks down. While the evidence base needs to be developed further, the estimation of user-benefits with fixed land use may provide a reasonable proxy for user-benefits with variable land use, capturing the welfare effects of most changes in the transport market."

- "Fourth, the welfare change associated with the move to more/less productive jobs is equal to the change in tax revenue."

In DfT (2016, 2019) equation 5 reproduced below, the i subscripts have been replaced with j subscripts to emphasize that these are work area values rather than home area values. Furthermore, a subscript has been added to ΔGDP^{f}_{M2MLPJ} to highlight that these are GDP changes attributable to M2MLPJ.

Equation 5 GDP Impacts of M2MLPJ
$\Delta GDP^{f}_{M2MLPJ} = GDPW^{B,f} \sum_j (E^{A,f}_j - E^{B,f}_j)\, PI_j, \quad \forall f$
ΔGDP^{f}_{M2MLPJ} are the GDP changes associated with existing workers moving to more/less productive jobs (M2MLPJ) in each forecast year f.
$GDPW^{B,f}$ is average national GDP per worker in the baseline scenario B. These values vary by forecast year f, and are available in the "tag-wider-impacts-dataset-July-2021.xlsx" workbook, in worksheet "National GDP per worker". These values are labelled $GDPW^{N,f}$ in the worksheet "README", where N stands for *national*.
$E^{A,f}_j$ is total employment in work area j in the alternative scenario A, by forecast year f. These employment values need to be computed based on the estimated impacts of A.
$E^{B,f}_j$ is total employment in work area j in the existing baseline scenario B, by forecast year f. These employment values are available in the "tag-wider-impacts-dataset-July-2021.xlsx" workbook, in worksheet "Total Employment". These values are labelled $E^{0,f}_I$ in the worksheet "README", where 0 stands for the *do minimum scenario*.
PI_j is the zonal productivity differential per worker in each area j. The rate of technological progress is assumed constant so this will not vary by forecast year. These values are available in the "tag-wider-impacts-dataset-July-2021.xlsx" workbook, in worksheet "Productivity per Worker". These values are labelled PI_I in the worksheet "README".

While modelling all the elements within equation 5 can be complicated, the computation of equation 5 is relatively straightforward. It is just the change in employment in each work area $(E^{A,f}_j - E^{B,f}_j)$ multiplied by the productivity differential in the work area (PI_j), then summed across all work areas j to give the net national change in productivity per worker. This solution is then multiplied by average national output per worker $(GDPW^{B,f})$ to estimate the national change in productivity in a given forecast year f.

The two versions of equation 6 below provide estimates of the wider impacts $(WI2^{f})$ from these M2MLPJ productivity changes. Its value in each forecast year f is simply the constant average tax wedge multiplied by future changes in GDP (ΔGDP^{f}_{M2MLPJ}) brought about by the M2MLPJs from the alternative transport scenario. Two versions of equation 6 are presented, with either tax wedge τ_1 or τ_3 used as a coefficient. The notation and definitions presented below are an attempt to reconcile those found in DfT (2016, 2019) to those in DfT (2014, 2018 section 5.3.2) and worksheet "README" of workbook "tag-wider-impacts-dataset-July-2021.xlsx".

Equation(s) 6 Wider M2MLPJ Impacts
$WI^{f}_{M2MLPJ} = \tau_3 \Delta GDP^{f}_{M2MLPJ}, \quad \forall f$
WI^{f}_{M2MLPJ} are the welfare changes with the move to more/less productive jobs and will vary depending on the forecast year f. This replaces $WI2^{f}$ in TAG A2.3 to clarify the notation.
τ_1 is the average tax wedge rate already defined in equation 2. This is used in DfT (2016, 2019).
τ_3 it the tax take rate on the Move to More/Less Productive Jobs. This is the estimated tax take of GDP changes from existing workers becoming more/less productive and hence attracting a marginal income tax as well as an increased operating surplus. This is used in DfT (2014), DfT (2018) and WITA software.

Notes: In DfT (2016, 2019) equation 6 is specified as: $WI^{f}_{M2MLPJ} = \tau_1 \Delta GDP^{f}_{M2MLPJ}$. It is recommended that henceforth equation 6 be specified using τ_3 and state if its value equals τ_1.

A partial derivative can be used to assess the effect of changing the tax wedge (τ_3) on workers M2MLPj:

- $\frac{\partial W21^{f}}{\partial \tau_3} > 0$, thus, a larger tax wedge leads to greater *wider impact* gains from transport investments that increase the gains from M2MLPJ.

3 Literature review of labour supply elasticity

Key points: This section reviews the literature on labour supply elasticities in the UK and other countries. The goal is to determine whether the labour supply elasticity ε^{LS}= 0.10 currently used in TAG A2.3 is appropriate. Given this elasticity is used to model the decision of individuals to enter or exit employment, the emphasis is on labour supply elasticity estimates at the *extensive margin*. Moreover, given that this parameter was specified by the DfT around the year 2000, it is fitting to focus on post-2000 general population estimates for the UK. Such estimates are provided in Table 3.3.1 of subsection 3.3 and we interpret these as suggesting a labour supply elasticity of ε^{LS}= 0.22, or possibly higher.

3.1 Labour supply elasticity fundamentals

In TAG A2.3, the labour supply elasticity is assumed to be 0.10 (10%), defined as the proportionate change in employment divided by the proportionate change in wages that caused it. Based on the previous discussion of the employment equation 2 and the change in GDP equation 3 it is clear that this is an *extensive elasticity*. Extensive elasticities measure the propensity for an individual to enter, or exit, employment in response to a change in the wage level on offer. In contrast, intensive elasticities measure the responsiveness of existing workers to change their labour supply in response to changes in the wage rate. Though this literature review includes both extensive and intensive labour-supply to wage elasticities, the former is clearly of greater relevance for the TAG A2.3 models.

Labour supply elasticities can be computed at the microeconomic or macroeconomic level. Micro elasticities focus on the labour-supply behaviour of individuals or households and are based on microeconomic data, such as national Labour Force Surveys. In contrast, macro elasticities focus on the overall labour supply across time in an economy as a whole, or across regions and perhaps time.

For illustrative purposes, the following clarifying definitions are useful. An individual's decision to work more hours if their wage rate increases would be captured by an intensive micro elasticity. An increase in the total hours worked in an economy, in response to a rise in the general wage level, would be captured by an intensive or extensive macro elasticity. An individual's decision to move into employment if the offered wage rate increases constitutes an extensive micro elasticity. An increase in the total number of employed workers in response to a rise in the general wage level would be an extensive macro elasticity.

It should be noted that total or 'overall' elasticities are often also computed, by combining the intensive and extensive elasticities in some manner, but papers vary in terms of how this combination is achieved.[18] In what follows, the delineation between the two elasticity types maintained as far as possible in order to be clear on what is being captured. It should also be noted that, given that these are elasticities, the units of measure are not relevant because both the currency units and time interval cancel out in the definition of an elasticity. In other words, factors like the currency that pay is specified in, the pay period, etc. are of little consequence. The equation below presents a simple example for an intensive elasticity to illustrate why the units of measure cancel out, be they time-units or currency units:

$$\begin{aligned}\varepsilon &= \frac{\frac{42\text{weekly hours} - 40 \text{ weekly hours}}{40 \text{ weekly hours}}}{\frac{\pounds 12/\text{hour} - \pounds 10/\text{hour}}{\pounds 10/\text{hour}}} \\ &= \frac{(42-40)/40}{(12-10)/10} \\ &= 0.25\end{aligned}$$

Another issue considered in some publications is the distinction between pre-tax gross earnings and post-tax net earnings, and its impact on labour supply elasticity. Given that elasticity represents a proportionate change, the gross/net distinction does not matter if the tax rate on earnings is constant, or at least constant over the relevant range for a worker on mean or median earnings. However, in most countries, the tax rate is progressive with respect to earnings. This means that elasticities calculated on the basis of gross versus net earnings might differ if workers experience a change in earnings substantial enough to place them in a different tax bracket.[19] Whether these changes are substantial enough might be an empirical matter specific to each transport proposal. On balance, assuming that there is an equivalence between the labour-supply elasticity on gross and net earnings seems a reasonable working assumption.

Most studies that compute net earnings do so by initially estimating equations based on gross earnings. They then model the effect of taxes in a second stage, using tax rule calculations. Table 3.3.1 is the only one that includes footnotes documenting the gross/net distinction. This is because the UK-focused publications it lists are of primary interest to the present study.

In published work spanning the last fifty years, labour supply elasticities have been estimated in various contexts. Studies have varied in terms of territories, time periods, and population segments. A variety of different estimation methods have been applied and they have drawn upon different sources for their data. Before

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[18] Blundell & Shephard (2012, footnote 9) provide a useful summary of total elasticity: “The total hours elasticity η_t is related to the intensive and extensive elasticities (respectively η_i and η_e) according to $\eta_t = \eta_i + (Q/P)\eta_e$. Here, P denotes the employment rate, and Q is the ratio of average hours of new workers, relative to the initial average hours of existing workers.”

[19] We are grateful to an anonymous referee for highlighting this point.

reviewing some of the literature, it is useful to provide a general overview of the scope of work.

Studies that considered the UK are of most interest for the purposes of this report and are summarised in Tables 3.2.1 and 3.3.1 below. However, papers that have focused on the US and Canada (Tables 3.2.2 and 3.3.2) and elsewhere (Tables 3.2.3 and 3.3.3) are also under consideration.

Regarding the time periods under consideration, Section 3.2 focuses on papers published prior to the year 2000, whilst Section 3.3 those published after 2000. The choice of 2000 as a cut-off year is motivated by two considerations. First, more recent work might be given more weight when recommending appropriate present values for the labour supply elasticity. Second, also of interest is the historical context within which the labour supply elasticity of 0.10 was chosen when TAG A2.3 was first published around the year 2000.

Clearly, the years under analysis pre-date the years of publication, with some published papers drawing upon data from much earlier time periods. Examples of this include French (2005), Ziliak and Kniesner (2005) and Chang and Kim (2006), all of which draw on pre-2000 data. There is also work such as Blundell et al. (2007) and Blundell, Bozio & Laroque (2011) which consider periods either side of the year 2000 threshold, with datasets spanning 1978-2001 and 1978-2007 respectively.

Regarding the sampled population, studies used to estimate labour supply elasticities have been motivated by various research agendas and have therefore examined diverse sub-samples. For example, a large proportion of studies focus on how women respond to wage changes. Two recent examples include Blundell et al (2016) and Attanasio et al (2018), but the consideration of female labour supply has been of great interest since the 1960s, as highlighted in the survey work of Killingsworth and Heckman (1986). An early example of this work looking at the labour supply of married women is Mincer (1962). A smaller proportion of research papers have focused exclusively on men. A slightly greater proportion of studies have sought to compare the labour supply elasticity of men and women, often considering their marital or relationship status and how this influences their decisions (see Triest, 1990; Borella et al, 2019; Theloudis, 2021). Whether men and women have children (e.g. Keane and Moffitt, 1998; Jones and Nasir, 2020) in and out of relationships (e.g. Blundell et al, 2000, or countless US studies) has also been examined. The labour supply elasticities of single mothers have been a particular focus (with numerous studies including Ermisch and Wright, 1991; Eissa and Liebman, 1996; Haan and Wrohlich, 2015). Several studies have considered the effect of differences in education levels (for example Barth and Dale-Olsen, 2009; Meghir and Phillips, 2010; Ishakov and Keane, 2021). The analysis of different sub-samples typically aims to inform policy within a given area.

Note that studies that look at specific industries or particularly narrow groups are not included in the tables below, nor in the surrounding discussion. For instance, some scholars have specifically considered the labour supply elasticities of nurses. This includes Rice (2005) who computed an intensive elasticity of 0.15 and extensive elasticity of 1.40, and Crawford, Disney and Emmerson (2015) who computed an extensive elasticity of 0.07. In another example on nursing, recent work by Georgiadis and Franco Gavonel (2023) considered care homes during the COVID-19 pandemic, computing an extensive elasticity of 0.90. Outside of nursing, Brown (2013) computed an extensive elasticity of 0.18 for teachers near retirement. Papers such as these are omitted from the discussion because the main objective of this literature review is to provide an overview of labour supply elasticities that are representative of the workforce as a whole and not specific industries.

Regarding estimation methods, various models and econometric techniques have been used to estimate labour supply elasticities. Whilst a very brief overview of approaches is given here, see Evers, De Mooij and Van Vuuren (2008) or Bargain and Peichl (2016) for more thorough account of the empirical techniques that have been used in the literature. Some papers use maximum likelihood techniques to estimate structural models (for example, Euwals and van Soest, 1999) or discrete choice models (Geyer, Haan and Wrohlich, 2015). Structural models can also be seen in the work of Park (2020) and Azar et al (2022). Others survey and consider a variety of model types. For instance, Adam and Phillips (2013) feature linear and quadratic models as well as structural and discrete choice models. Older work by Blundell and Walker (1986) used ordinary least squares estimation of Cobb-Douglas and Translog models. Two-stage least squares has been used by, for example, Jäntti et al (2015). Instrumental variables were also utilised in Altonji (1986) and Bingley and Lanot (2002). Recent work by Lo (2023) considered a search friction model. This variety in methods highlights the fact that there are many different ways of estimating labour supply elasticities and no one approach is universally agreed-upon.

3.2 Pre-year-2000 labour supply elasticity estimates

In this section, research published prior to the year 2000 is considered. As discussed in Section 3.1, part of the motivation for this is to better understand why the labour supply elasticity of 0.10 is used in the current TAG A2.3. More generally, it is important to understand how estimates for elasticities have evolved over time. In what follows, themes and patterns are identified in the relevant published work.

Table 3.2.1 summarises literature that examined labour supply elasticities in the UK, spanning the from the mid-1970s to the year 2000. Note that in this and the tables that follow, all values are for microeconomic elasticities except in the few cases where these are explicitly indicated as macroeconomic elasticities.

UK papers published in the 1970s and most of those published in the 1980s focused on men or, occasionally, couples. By couples these invariably refer to households containing two working-age married adults, and these studies sought to capture the collective household labour participation. To this end, the majority of the early studies computed extensive (participation) elasticities.

Much of the work published before 1985 produced what would considered 'unusual' estimates. Five of the first six papers listed in Table 3.2.1 generated a range of elasticities that included negative values. This is interesting because a negative value suggests that an increase in the wage level on offer corresponded to a decrease in employment participation. Though this seems counterintuitive, it may be understandable in the context of the time. By way of explanation, all of these studies were based on data from the 1970s and this period coincided with changes in social insurance benefits (see, for example, Siebert 1997). Negative labour supply elasticities might emerge if, when faced with an hourly wage increase, workers choose to work fewer hours in order not to exceed an earnings threshold that would disqualify them from other state benefits. This is commonly known as one of the 'poverty trap' effects. Attempts to avoid these poverty trap effects can be seen in today's tapered loss of state Child Benefits for those earning between £50000 and £60000 (see, for example, Bourne, 2014).

Many UK studies published before 1990 used relatively limited samples insofar as they examined data from just a single year. Part of the reason for this might have been the limited computing facilities of the time. For instance, Layard (1978) drew upon the 1974 General Household Survey (GHS). As time progressed, repeat surveys meant these datasets expanded and by the 1990s the samples used in the UK literature had begun to grow. For example, the GHS first ran in 1971 and continued almost every year until 2007. Later studies that used the GHS had a greater pool of data to draw from. For example, Ermisch and Wright (1991) used 1973-1982 GHS data. However, data availability was not the sole explanation for the use of limited datasets in early studies. Browning, Deaton and Irish (1985) is something of an outlier amongst the early UK studies in that it did examine a more extensive period using the UK Family Expenditure Surveys (FES) from 1970 to 1977. Blundell and Walker (1986), published a year later, only drew upon the 1980 edition of the FES. This implies that in many cases scholars chose to limit the number years they analysed.

Table 3.2.1 – UK pre-2000 (selected studies)

Publication	Labour supply elasticities		Sample period	Sample population
	Extensive margin	**Intensive margin**		
Brown, Levin & Ulph (1976)	-0.13 to 0.22		1976	Married men
Layard (1978)	-0.13 to -0.09		1974	Married men
Atkinson & Stern (1980)	-0.16 to -0.09		1973	Men
Greenhalgh (1980)	0.355	0.637 to 0.717	1971	Married women
Blundell & Walker (1982)	-0.23 to 0.13		1974	Couples
Blundell & Walker (1983)	-0.004 to 0.2		1977	Couples
Browning, Deaton & Irish (1985)		0.09	1970-1977	Men (Macroeconomic)
Arrufat & Zabalza (1986)	1.41	0.62	1974	Married women
Blundell & Walker (1986)	0.026 to 0.033		1980	Women
	0.009 to 0.024		1980	Men
	-0.07 to 0.024		1980	Couples
Blundell, Ham & Meghir (1987)	0.04 to 0.08		1981	Women
Walker (1990)	0.7		1979-1984	Single women with children
Ermisch & Wright (1991)	1.2 to 1.8		1973-1982	Single women with children
Arellano & Meghir (1992)		0.29 to 0.71	1983	Women with children
Blundell, Duncan & Meghir (1992)	0.34	0.11 to 0.52	1981-1986	Single women with children
Jenkins (1992)	1.8		1989	Single women with children
Blundell, Duncan & Meghir (1998)		0.13 to 0.44	1978-1992	Women with children
Blundell et al (2000)		0.11 to 0.17	1994-1996	Women in couples

In contrast to studies of the UK, in the North American literature it became common to utilise a longer dataset at an earlier point. Table 3.2.2 summarises work that examined the US and Canada from the mid-1970s through to the year 2000. One can see that from the 1980s it was common for researchers to utilise data for multiple years, in part as a result of the data availability. For example, papers like MaCurdy (1981) and Altonji (1986) utilised the rich Michigan Panel Study of Income Dynamics (PSID). However, the use of larger datasets was the norm amongst US scholars from an early point. In general, larger datasets typically produce results with tighter confidence bands and more scope for exploring multiple causal factors and focusing on sub-categories of respondents. This, combined with the differences in social insurance systems between the UK and US, may explain why the US literature has fewer of the 'unusual' negative labour supply elasticity estimates found in some early UK studies.

Table 3.2.2 – US and Canada pre-2000 (selected studies)

	Labour supply elasticities			
Publication	**Extensive margin**	**Intensive margin**	**Sample period**	**Sample population**
Mincer (1962)		1.5	1950	Married women (Macroeconomic)
Heckman (1976)		0.8	1967	Women
Wales & Woodland (1976)		0.11 to 0.49	1971	Couples
Cogan (1981)		0.86 to 2.40	1967	Married women
Hausman (1981)		0.00 to 0.77	1975	Married men
		0.90 to 1.00	1975	Married women
Moffitt (1984)	1.25		1967-1975	Women
Altonji (1986)		0.17	1968-1981	Men
Altug & Miller (1990)		0.14	1967-1980	Men
MaCurdy, Green & Paarsch (1990)	0 to 0.07	-0.24 to 0.03	1975	Married men
Triest (1990)		0.03 to 0.28	1983	Women, married or in couples
Dickert, Houser & Scholz (1995)	0.35		1990	Single women with children
Carrington (1996)	0.43		1968-1983	Men & women
Eissa (1996)	0.65 to 1.00	0.6	1981, 1985	Married women
Eissa & Liebman (1996)	0.3 to 1.16		1984-1990	Single women with children
Keane & Moffitt (1998)	0.96		1989	Single women with children
Kimmel & Kniesner (1998)	0.86	0.39	1983-1986	Married men
	1.85	0.67	1983-1986	Married women
Ziliak & Kniesner (1999)		0.16	1978-1987	Married men
Eklöf & Sacklén (2000)	0 to 0.036		1975	Married men

Amongst the pre-2000 UK literature, Arrufat and Zabalza (1986) stands out as an outlier. One of the first UK papers to consider married women alone, this study computed higher values of elasticity when compared to other UK papers around this time, particularly in terms of the extensive (participation) elasticity. Indeed, they produced results more akin to those in the US literature. As Arrufat and Zabalza (1986, p.58) note, *"we obtain overall elasticities that are larger than those obtained by Layard […] and by Greenhalgh […] Our results, however, are quite comparable to those obtained with American data"*. When one looks at the computed elasticities in the US and Canada, it is clear from Table 3.2.2 that values for the US were generally higher than those for the UK.

Given the focus of this review is the UK, the findings for the US are not emphasized. That said, two prominent US papers are worth mentioning. Hausman (1981) and MaCurdy, Green and Paarsch (1990) both used data from the 1975 Population Study of Income Dynamics (PSID) and yet came up with quite different results as summarised in Table 3.2.2. These differences have been discussed in the literature, see for instanced Eklöf and Sacklén (2000). The contrasting estimates from these two papers demonstrate the differences and difficulties in estimating labour supply elasticities. The same underlying data can produce very different results under different estimation methods.

A noticeable feature of work on the UK is the type of elasticity that was estimated. In very early work, extensive (participation) elasticities were much more common. Into the 1990s, intensive elasticities took over as the dominant type. This is in contrast to the US literature where estimates of both types of elasticities were initially equally common. In later years, the move in the US and Canada was in the opposite direction with papers in the 1990s tending to include estimates of extensive elasticities. Another noticeable feature in the UK and North American papers is the motivation behind the research and the sample under analysis. Through much of the 1980s and 1990s, women were the subject of most academic work on UK labour supply elasticities. The same was not true in the US, where papers continued to examine both sexes.

What impact might this have had on policy advisers? At a glance, the labour supply elasticity estimate of 0.10 in the first DfT guidance seems low when compared to the values in Table 3.2.1, particularly if one adopts the interprets the intensive labour supply elasticity as the relevant definition. However, when one considers that papers published immediately before the DfT guidance came out focused on women, the 0.10 value seems more reasonable if a parameter representative of both sexes was needed. In general, it is clear that male labour supply elasticities tend to be lower than female ones. This is apparent in the estimated values reported in Tables 3.2.1 and 3.2.2. For example, Blundell and Walker (1986) report estimates of 0.009 to 0.024 for men compared to 0.026 to 0.033 for women. Likewise, Kimmel and Kneiser (1998) suggest 0.39 intensive and 0.86 extensive elasticities for men and 0.67 intensive and 1.85 extensive elasticities for women.

Finally, a brief consideration is given to the rest of the world (other than the UK and North America). The majority of other work was conducted on European countries, with Sweden and the Netherlands receiving a lot of attention in the early literature. Table 3.2.3 gives a selection of the pre-2000 papers for the rest of the world. Features of these papers include datasets limited to a single year and the analysis of both men and women. Moreover, the majority of these studies examined men and women as couples. They also had a focus on the intensive margin, which is of less interest for the purposes of this study.

Table 3.2.3 – Rest of the World pre-2000 (selected studies)

Publication	Labour supply elasticities		Sample	Sample
	Extensive margin	Intensive margin	period	population
Blomquist (1983)	0.08 to 0.11		1974	Men, Sweden
Colombino and Del Boca (1990)	0.64	1.18	1979	Women, Italy
Blomquist and Hansson-Brusewitz (1990)		0.38 to 0.77	1981	Women, Sweden
		0.08 to 0.13	1981	Men, Sweden
Bourguignon and Magnac (1990)	0.1		1985	Couples, France
Van Soest, Woittiez and Kapteyn (1990)	0.12	0.35 to 0.59	1985	Women, Netherlands
	0.19	0.15 to 0.19	1985	Men, Netherlands
Flood and MaCurdy (1992)		-0.25 to 0.21	1983	Men & women, Sweden
van Soest (1995)		0.42 to 0.54	1987	Women, Netherlands
		0.05 to 0.09	1987	Men, Netherlands
Callan and van Soest (1996)	0.31	0.50 to 0.85	1987	Women, Ireland
		0.1 to 0.2	1987	Men, Ireland
Aaberge, Colombino and Strøm (1999)	0.65	0.74	1987	Women, Italy
	0.046	0.053	1987	Men. Italy
Euwals and van Soest (1999)		0.143 to 0.192	1988	Women, Netherlands
		0.054 to 0.154	1988	Men, Netherlands

3.3 Post-year-2000 labour supply elasticity estimates

In this section attention turns to literature published after the year 2000. Though subsequent editions of DfT guidance have been published, including iterations of the TAG A2.3, the labour supply elasticity value has remained unchanged through various revisions. If the value now warrants change, the post-2000 literature will inform this. It is therefore important to carefully consider how estimates have changed in published work over the past two decades.

As illustrated in Table 3.3.1, there seems to have been less published work on labour supply elasticities in the UK since the year 2000. This includes more details than other tables, given the relevance of recent UK publications to this study. Interest in UK female labour supply seemingly continued into the 2000s, before attention switched back to both sexes. It is also evident that the recent literature uses much larger samples, and is a consequence of increased data and computing availability. The small number of publications makes it difficult to draw firm conclusions about the size of the estimated labour supply elasticities, but these elasticities appear larger than those in pre-2000 literature.

Table 3.3.1 – UK post-2000 (selected studies)

	Labour supply elasticities			
Publication	**Extensive margin**	**Intensive margin**	**Sample period**	**Sample population**
Blundell et al (2007, p. 439)[20]		0.33	1978-2001	Women
Meghir & Phillips (2010, p. 247)[21]	0.27		1996-2004	Single men
	0.53			Married men
Blundell et al. (2011b, p. 486)[22]	0.25	0.23	1978-2007	Men
	0.34	0.09		Women
Blundell & Shephard (2012, Tab.3)[23]	0.770	0.042	1997-2003	Single mothers
Bargain et al. (2014, Appendix F)[24]	0.07	0.02	2001	Married women
	0.06	0.00		Married men
	0.24	0.04		Single women
	0.22	0.01		Single men
Blundell et al (2016, Table XIV)[25]	0.475	0.210	1991-2008	Women
Beffy et al (2018, Tab.10, model 1)[26]		0.58	1997-2002	Mothers
Jones & Nasir (2020, Table 8)[27]		0.02	2007-2015	Men, without child
		0.02		Men, with children
		0.12		Women, without child
		0.14		Women, with children

Notes: Shaded areas are used to calculate the proposed mean extensive margin elasticity of 0.22, with a range of 0.15 to 0.30. This mean value of 0.22 is derived by averaging the values from Bargain et al. (2014), which is 0.15, and from Blundell et al. (2011b), which is 0.30. In these calculations we assume each population sub-group within each study carries equal weight. The mean extensive margin elasticity would have been 0.32 had we also included Meghir & Phillips (2010) and Blundell et al. (2016), as a single study, in the calculations.
These are uncompensated (Marshallian) mean elasticities, apart from Blundell et al. (2011ab) and Joanes & Nasir (2020), where they are median elasticities. Some articles also report mean compensated (Frisch) elasticities: Beffy et al (2018, Table 10), Blundell & Shephard (2012, Table 3) and Blundell et al. (2016, Table XIV). See footnotes for whether pre-tax gross wages or post-tax net wages are used.

Particularly interesting are the results of Meghir and Phillips (2010) and Bargain, Orsini and Peichl (2014). Meghir and Phillips (2010) considered the education levels of men and women, finding that those with higher education had lower elasticities. This is consistent with results found by Menunni (2019) for the US, whose findings support the idea that more educated individuals have a much lower labour supply elasticity. A point of contrast between the two is that Meghir and Phillips produced extensive elasticities whereas Menunni's is of the intensive type. For the present purposes of

[20] Analysis based on pre-tax gross wages: "Of course, there are issues that we do not address; these include uncertainty, inter-temporal considerations, taxation, and others." (Blundell et al. 2007, p. 421)
[21] Analysis based on wages net of taxes: "The in-work and out-of-work net incomes are calculated using the IFS tax and benefit model (TAXBEN) and are derived using the full set of determinants of taxes and benefits as observed in the FRS [Family Resources Survey]." [Meghir & Phillips 2010, p. 246]
[22] Joint macroeconomic analysis on gross earnings for the UK, France and the US, with the UK the 'middle' case. These results were previously published in Blundell et al. (2011a, p.38).
[23] Analysis based on wages net of taxes.
[24] 'Baseline' analysis based on pre-tax gross wages, with additional analysis provided on net wages.
[25] Analysis based on incorporating tax rules in a model of pre-tax gross wages.
[26] Analysis based on wages net of taxes: "For every family in the data we have an accurate tax and benefit model (IFS-Taxben) that simulates the complete budget constraint incorporating all aspects of the tax, tax-credit and welfare systems … ." (Beffy et al 2018, p. 17)
[27] Based on gross pre-tax gross wages from UK Labour Force Survey data.

needing an extensive elasticity for the UK, clearly Meghir and Phillips (2010) is of greater interest. Another interesting observation, given the findings in section 3.2, are the results of Bargain, Orsini, and Peichl (2014). Their paper implies a higher labour supply elasticity for men compared to women, which is the opposite of most other findings in the literature. This is certainly not the case in the US, with papers consistently reporting higher elasticities for women compared to men (see Table 3.3.2). Indeed, Bargain, Orsini and Peichl themselves find higher estimates for women in the US data, so this is a quirk of this particular UK study.

Whilst the volume of work produced on the UK has decreased since 2000, this is not true of the US and Canada, where work in this area seems undiminished as illustrated in Table 3.3.2. Evidently, most of the published work in Tables 3.3.1 and 3.3.2 draws upon samples that end several years ago. For the UK, the vast majority of work in Table 3.3.1 utilises a sample that does not go beyond 2012. For the US there are a few papers that use more recent data, but the UK is of primary interest in this study. This data lag might be a consequence of publication lags. It takes time for data to be processed and become available to researchers, it then takes time for completed research to achieve publication. An exception is Jones and Nasir (2020), whose work consider more recent data, although only a series of observations from the second quarter of 2015. In general, the fact that findings are drawn from data that stem from a decade or more ago poses problems if one is to recommend an appropriate value of labour supply elasticity for the present. Moreover, Jones and Nasir suggest ‘unusual’ negative elasticities for men, which could potentially imply a change in behaviour in recent years. Until further evidence has been published one can only speculate in these negative elasticities.

The few papers that have been published in recent years that do draw upon more recent data are very specific in their scope. For the UK, the recent work by Georgiadis and Franco Gavonel (2023), as discussed earlier, examines the very specific market of care home workers during the COVID-19 pandemic. Recent work by Motghare (2021) does not feature in Table 3.3.2 because it specifically considers the labour supply elasticities of New York taxi drivers. As mentioned in Section 3.1, such specific papers are not relevant for this survey.

Finally, with respect to the rest of the world (territories other than the UK and North America), interest in Sweden and the Netherlands persisted in the post-2000 literature much as it had in the pre-2000 studies. In addition to these nations, post-2000 literature also focused on Germany in particular. It is worth noting the previous separation of Germany into East and West Germany. The studies in Table 3.3.3 were published after German re-unification and they all draw from samples after that point (1990). That said, Dearing et al (2007) is noteworthy because it specifically analysed couples from West Germany. All other studies considered the country as a whole, although differences may still persist from East to West.

Table 3.3.2 – US and Canada post-2000 (selected studies)

Publication	Labour supply elasticities: Extensive margin	Labour supply elasticities: Intensive margin	Sample period	Sample population
Meyer & Rosenbaum (2001)	0.43		1985-1997	Single women
Juhn, Murphy & Topel (2002)	0.13		1972-1973, 1988-1989	Men
Pencavel (2002)		0.12 to 0.25	1999	Men
Devereux (2003)	-0.061 to 0.001	-0.022 to 0.017	2003	Men
Devereux (2004)	0.17 (men & women)	0.00 to 0.07	1980-1990	Married men
		0.17 to 0.38		Married women
Eissa & Hoynes (2004)	0.03		1984-1997	Men with children
	0.27			Women with children
	0.03 to 1.15			Men & women with children
Imai & Keane (2004)	0.36 to 1.96		1979	Men
French (2005)	0.3 to 1.1		1968-1997	Men
Ziliak & Kniesner (2005)		-0.47	1980-1999	Men
Chang & Kim (2006)	0.9		1979-1992	Men
Blau & Kahn (2007)		0.01 to 0.07	1980	Married men (Macroeconomic)
		0.77 to 0.88	1980	Married women
		0.10 to 0.14	1990	Married men
		0.58 to 0.64	1990	Married women
		0.04 to 0.10	2000	Married men
		0.36 to 0.41	2000	Married women
Heim (2007)	0.66	0.36	1979	Married women
	0.03	0.14	2003	Married women
Bishop et al. (2009)	0.28	0.14	1979	Single women
	0.22	-0.03	2003	Single women
Heim (2009a)	0.00 to 0.003	0.04 to 0.07	2001	Men in couples
	0.07 to 0.18	0.24 to 0.33		Women in couples
Heim (2009b)	0.00	0.04 to 0.07	1999-2005	Married men
	0.07 to 0.17	0.24 to 0.33		Married women
Chetty (2012)	0.25	0.33	Combining various	Various
French & Jones (2012)	0.36 to 1.28		1968-2010	Men
Jacob & Ludwig (2012)		0.15	1990-2005	Chicago housing voucher applicants
Bargain, Orsini & Peichl (2014)	0.04 to 0.18	0.00 to 0.02	2005	Men
	0.12 to 0.19	0.02 to 0.03	2005	Women
Blundell, Pistaferri & Saporta-Eksten (2016)		0.30 to 0.40	1999-2009	Married women
Erosa, Fuster & Kambourov (2016)	1.08	0.67	1990	Men (Macroeconomic)
	1.11 to 2.74			
Keane & Wasi (2016)	0.29 to 1.25		1992-2012	Men
Attanasio et al (2018)	0.59 to 0.82	0.82 to 0.91	1980-2012	Women (Macroecon.)
Borella, De Nardi & Yang (2019)	0.40 to 0.70	0.40		Women
	0.3 to 1.8			Men
Menunni (2019)		0.20 to 1.50		Men
		0.30 to 1.70		Women
Park (2020)	0.28 to 0.59		1999-2011	Men & women (Macroeconomic)
Detilleux & Deschacht (2021)	0.869		2000-2019	Men with children
	0.514			Women with children
Azar et al (2022)	0.42		2009-2011	Men & women
Cairó, Fujita & Morales-Jiménez (2022)	0.25		1976-2016	Men & women
Bredemeier, Gravert & Juessen (2023)		0.65	1999-2019	Men
		0.80	1999-2019	Women

Table 3.3.3 – Rest of the World post-2000 (selected studies)

Publication	Labour supply elasticities: Extensive margin	Labour supply elasticities: Intensive margin	Sample period	Sample population
Bianchi, Gudmundsson, and Zoega (2001)	0.42		1987	Men & women, Iceland
van Soest and Das (2001)		0.67 to 0.74	1995	Women, Netherlands
		0.07 to 0.10	1995	Men, Netherlands
Bingley and Lanot (2002)		0.14	1980-1991	Men & women, Denmark
Blomquist and Newey (2002)		0.04 to 0.12	1973,1980,1990	Men, Sweden
Schneider, Kempe and Bonin (2002)	0.2	0.27	1999	Women, Germany
	0.19	0.21	1999	Men, Germany
Laroque and Salanie (2002)	0.36 to 0.96		1999	Women, France
Van Soest, Das and Gong (2002)	0.35 to 0.58	0.83 to 1.36	1995	Women, Netherlands
Aaberge, Colombino and Wennemo (2002)	0.06 to 0.51	0.1 to 0.66	1993	Women, Italy
	0.02 to 0.08	0.11 to 0.12	1993	Men, Italy
Fernandez-Val (2003)		0.31	1994-1995	Women, Spain
García and Suárez (2003)	1.51	0.37	1994-1995	Women, Spain
Flood, Hansen and Wahlberg (2004)		0.12	1993	Women, Sweden
		0.00	1993	Men, Sweden
Steiner and Wrohlich (2004)	0.04 to 0.2	0.08 to 0.56	2002	Women, Germany
	0.027 to 0.38	0.08 to 0.46	2002	Men, Germany
Bargain and Orsini (2006)	0.08 to 0.38	0.09 to 0.45	1998	Women, Germany
	0.46 to 0.58	0.52 to 0.65	1994-1995	Women, France
Brink, Nordblom and Wahlberg (2007)	0.15	0.18	1999	Women, Sweden
	0.00	0.06	1999	Men, Sweden
Dearing et al (2007)	0.07 to 0.19		2004	Women, Austria
	0.13 to 0.24		2004	Couples, Germany
Donni and Moreau (2007)		0.24 to 0.59	2001	Women, France
Clauss and Schnabel (2008)	0.14 to 0.18	0.37 to 0.38	2004-2005	Women, Germany
	0.17	0.23	2004-2005	Men, Germany
Labeaga, Oliver and Spadaro (2008)	0.11 to 0.26	0.01 to 0.29	1995	Men & women, Spain
Callan, van Soest and Walsh (2009)		0.71 to 0.90	1995	Women, Ireland
		0.21 to 0.31	1995	Men, Ireland
Bargain et al (2010)	0.04 to 0.20	0.06 to 0.34	2003	Women, Germany
	0.04 to 0.13	0.05 to 0.20	2003	Men, Germany
Agbahey, Siddig and Grethe (2020)	0.072		2000-2015	Men & women, Palestine
Ishakov and Keane (2021)	0.3 to 1.8	0.15 to 0.20	2001-2016	Men, Australia
Kim, Shim and Yang (2022)		0.23	2000-2018	Couples, Korea

4 Literature review of labour tax wedges

Key points: This section begins by presenting OECD estimates of the tax wedge for the UK from 2000 to 2022, as detailed in subsection 4.1. These estimates are useful for determining, and largely confirming, the validity of calibrating two of the TAG A2.3 tax wedge parameters to τ_1= τ_3= 0.30 for those moving into and out of 'inactivity'[28] and for those M2MLPJs respectively.

Although these two tax wedges could differ, due to demographic differences in these two groups of (potential and actual) workers, there currently is no empirical evidence upon which differing values could be calibrated. An additional reason to keep these values separate is the possibility of a future government introducing substantially different tax arrangements for new workers. For instance, tax relief or employer subsidies could be introduced to encourage the employment of new workers.

Currently, there is limited evidence to support calibrating the remaining tax wedge parameter to τ_2= 0.40. In the absence of a dedicated empirical study, a value of 0.40 appears to be a reasonable working value.[29] As is standard in these analyses, it is assumed the sample under analysis for all these tax wedges is the working age population, typically, aged 18 (or 16) to 64 (or 69) for the UK, and full-time students are excluded from the analysis.

Subsequent sub-sections provide a detailed review of the literature on labour tax wedges and their relationship to related topics, including effective tax rates, tax policy, personal income tax, and the employment effects of tax policies. This review supplements the explanations found in the TAG A2.3 model (DfT 2016, 2019), particularly in equations 2, 3, 4, and 6, by drawing on insights from the literature on labour income taxation and its impact on employment. The discussion begins with some fundamental details about tax wedges, followed by a review of literature focused on effective tax rates, tax policy, and the effects of taxation on income, employment, and welfare.

4.1 OECD estimates of the UK tax wedge

Since 1999, the OECD has released yearly reports 'Taxing Wages,' which include tax rate and tax wedge estimates for its member countries, including a detailed discussion of how these are calculated. The latest of these reports is OECD (2023a),

[28] The International Labour Organization definition of 'inactive' includes those of working age who are out of work, are not seeking employment and are not waiting for an existing job placement to begin.
[29] There is some ambiguity as to whether the difference between τ_1= 0.30 and τ_2= 0.40 is due to unemployment benefits (UB) or out-of-work benefits excluding UB (OoWBxUB). We interpret this difference as being due to OoWBxUB, given the TAG indicates that it is the number who are 'inactive' are modelled as moving into and out of employment while keeping the number 'unemployed' constant.

and the OECD defines a tax wedge as the ratio of the amount of taxes paid to the corresponding total labour cost for the employer. This average tax wedge indicates the extent to which tax on labour income may discourage employment and is expressed as a percentage of the total labour cost.

Below is a summary of the OECD procedures for estimating tax wedges for its member states as described in the Overview and Annex A of OECD (2023a). At the outset, two points are worth highlighting. One is that all calculations are based on the average gross hourly wage, which are believed to result in estimates that are closer to mean-average annual wages than median-average annual wages. The other is that the calculations are not based on actual tax takes, instead, they are based on the application of known tax rules.

- OECD recommends beginning with a measure of average gross hourly wage. It is not specified if this is the mean or median wage but the former seems more likely. For the UK the dataset used is the ‘Annual Survey of Hours and Earnings’ which is a 1% sample of the ‘Pay as You Earn’ data.
- The guidance is then to multiply the gross hourly wage by the average working hours for the standard time interval used in the survey, typically a week in UK surveys, and then scaled up to generate annual earnings.[30] For the UK the 2022 average gross annual wage turned out to be £44,300, see OECD (2023a, Table A.6).
- Eight different household types are then generated, where any children “are assumed to be aged between six and eleven inclusive”:
    - Single person on 100% of average wage, without children.
    - Single person on 67% of average wage, without children.
    - Single person on 167% of average wage, without children.
    - Single person on 67% of average wage, with two children.
    - Couple on 100% and 0% of the average wage, with two children.
    - Couple on 100% and 67% of the average wage, with two children.
    - Couple on 100% and 100% of the average wage, with two children.
    - Couple on 100% and 67% of the average wage, without children.
- Thereafter national tax rules are applied to calculate employer NI contributions, employee NI contribution, direct taxation, tax allowances and cash transfers. In some countries for some years, as for the UK, payroll taxes are also applied. For an example of detailed calculations see the United Kingdom section in OECD (2023a, pages 625-634).
- The tax wedges are then calculated as the ratio net tax deductions to the gross wage for each household type.

[30] This procedure cannot be interpreted as more likely to generate a mean or median annual wage.

The OECD (2023b, see https://data.oecd.org/tax/tax-wedge.htm) provides easy access to tax wedge estimates. These estimates focus on nationally representative workers who are single, have no children and are on the average national salary, but estimates are also provided for seven other population-representative groups. In OECD (2023a, Introduction) definitions are provided for tax wedges and tax rates. Selected text is provided below, arranged for the purposes of this report:

> *Taxing Wages* presents several measures of taxation on labour. Most emphasis is given to the tax wedge, a measure of the proportionate difference between labour costs to the employer and the corresponding net take-home pay of the employee. This indicator is calculated by expressing the sum of personal income tax, employee plus employer SSCs together with any payroll tax, minus benefits as a percentage of labour costs. Employer SSCs [social security contributions] and – in some countries – payroll taxes are added to gross wage earnings of employees in order to determine a measure of total labour costs. (OECD 2023a, pages 20-21)
>
> In *Taxing Wages*, the term 'tax' includes personal income tax, SSCs and payroll taxes (which are aggregated with employer SSCs in the calculation of tax rates) payable on gross wage earnings. Consequently, any income tax that might be due on non-wage income and other kinds of taxes – such as corporate income tax, net wealth tax and consumption taxes – are not taken into account. The transfers included are those paid by general government as cash benefits, usually in respect of dependent children. (OECD 2023a, page 20)

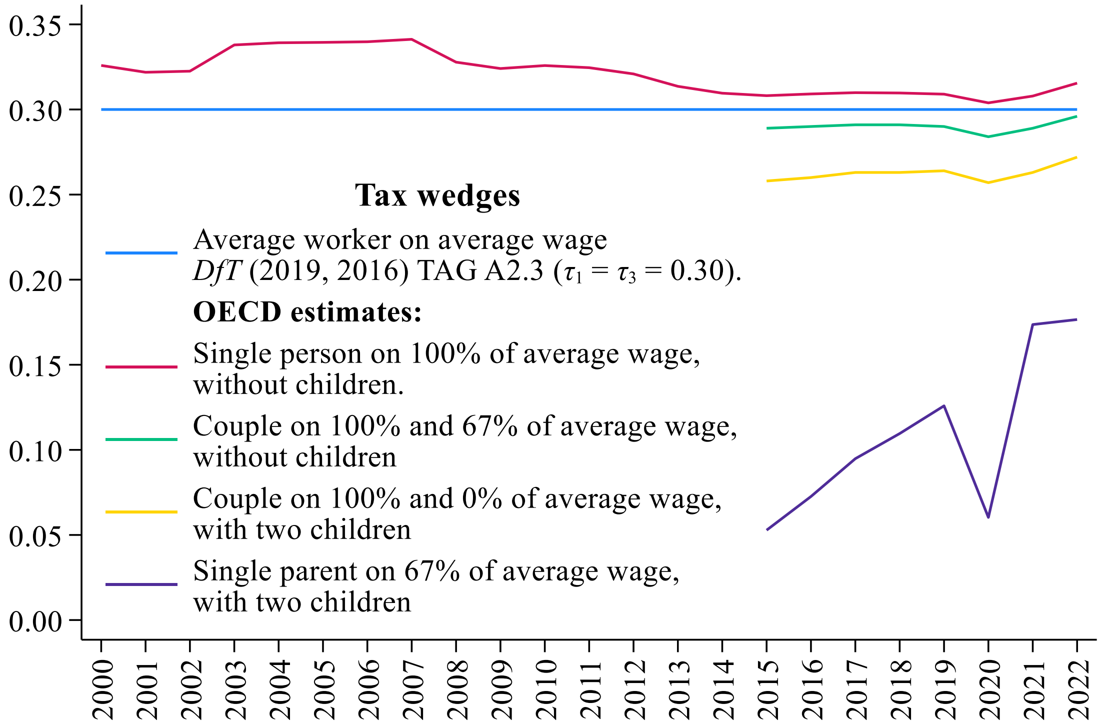
In OECD (2023a, Annex A) further clarification is provided on how the OECD differentiates between tax rates and tax wedges:

> The Report is concerned with personal income tax and employee and employer social security contributions payable on wage earnings. In addition, payroll taxes (see section on Payroll taxes) are included in the calculation of the total wedge between labour costs to the employer and the corresponding net take-home pay of the employee." [OECD 2023a, page 658] Payroll taxes are included in total tax wedges reported in this publication, given that they increase the gap between gross labour costs and net take-home pay in the same way as income tax and social security contributions do. The main difference with the latter is that the payment of payroll taxes does not confer an entitlement to social security benefits. Also, the tax base of payroll taxes may differ from the tax base of employer social security contributions. [OECD 2023a, page 660]

Figure 4.1 illustrates OECD (2023b) tax wedge estimates for the UK, and they seem to align with the TAG A2.3 tax wedge faced by the average new worker (τ_1= 0.30) or average existing worker who M2MRLP (τ_3= 0.30). This alignment is despite the fact that the OECD definitions of labour taxes are based on microeconomic computations while the DfT definitions seem based on macroeconomic estimates. The DfT macroeconomic approach is outlined in TAG A2.3 (DfT 2019, sections 3.2.10 and 3.3.10) where it states: "Estimate tax wedge associated with increased GDP". The OECD justifies its microeconomics approach on the basis that its focus is on how taxes influence economic decisions at the individual level. This decision has its practical advantages insofar as it is simpler to present the calculations based on each nation's definition of what taxes are earmarked for labour. For corporate tax, the OECD produces separate reports. The DfT's approach, which includes corporation tax in the labour tax wedge, operates under the assumption that labour ultimately bears all (or most) of the tax burden. Neither approach includes indirect taxes (e.g. VAT) in the labour tax wedge and neither approach considers that the tax burden may be shared between labour and employers as a consequence of the relative elasticities of labour demand and supply.

The OECD (2023a, https://www.oecd-ilibrary.org/taxation/taxing-wages-2023_64e1404a-en) report also includes Section 6 on the 'evolution of effective tax rates on labour income'. Some of these tax wedges for the UK in the period 2015 to 2022 are illustrated in Figure 4.1. They include tax wedges for: a single parent with two children on 67% of the average wage (OECD 2023a, Table 6.4, https://stat.link/iv2wzf), a one-earner married couple with two children on 100% of the average wage (OECD 2023a, Table 6.5, https://stat.link/z4vybq), and a two-earner married couple each on 100% and 67% of average wage without children (OECD 2023a, Table 6.8, https://stat.link/mc7hly). All tax wedge rates in Figure 4.1 show a dip in 2020, coinciding with the peak of the COVID-19 pandemic during which various tax relief measures were implemented. These included but were not limited to: Coronavirus Job Retention Scheme (furlough scheme), Self-Employment Income Support Scheme, and Statutory Sick Pay Rebate.

Figure 4.1: OECD (2023) UK tax wedge estimates and TAG A2.3 tax wedge value



Sources: OECD (2023a) https://www.oecd-ilibrary.org/taxation/taxing-wages-2023_64e1404a-en
OECD (2023b): https://data.oecd.org/tax/tax-revenue.htm

The effective tax rate (ETR) offers a useful analogue to the tax wedge. While tax wedges represent the total tax burden on labour, ETRs measure the total tax burden on any economic entities, which can include individual workers, private companies, public sector organizations, charities, or any other distinct entity. Whether one is greater than the other can depend on what is included in the taxes and whether subsidies are factored in. The OECD estimates of ETRs in Table 4.1 are based on macroeconomic aggregates. The OECD’s ETR on personal income is defined as the taxes levied on the net income (gross income minus allowable tax reliefs), excluding other levies such as NI, and capital gains of individuals as a proportion of GDP. The OECD's ETR on goods and services is defined as the ratio of all taxes levied on the production, extraction, sale, transfer, leasing, or delivery of goods, as well as the rendering of services, or on the use of goods or the permission to use goods or perform activities, to GDP. These taxes on goods and services mainly consist of value-added and sales taxes.

Table 4.1: OECD estimates of the % UK tax wedge, tax revenue rate and effective tax rates (ETR) for worker who is single, without children and on average salary

Year	Tax wedge	Tax revenue rate	ETR on personal income*	ETR on goods & services	Combined ETR burden
2000	32.590398	32.744	9.480	10.570	20.050
2001	32.188070	32.324	9.725	10.372	20.097
2002	32.251521	31.472	9.354	10.413	19.767
2003	33.794608	31.163	8.868	10.425	19.293
2004	33.920048	32.128	9.046	10.405	19.451
2005	33.943313	32.506	9.298	9.969	19.267
2006	33.981118	32.747	9.446	9.793	19.239
2007	34.123721	32.806	9.737	9.752	19.489
2008	32.781770	32.038	9.665	9.597	19.262
2009	32.407154	30.909	9.366	9.233	18.599
2010	32.582675	31.960	9.119	10.133	19.252
2011	32.456784	32.712	9.162	10.968	20.130
2012	32.091517	31.977	8.761	10.850	19.611
2013	31.361598	31.798	8.732	10.788	19.520
2014	30.956356	31.458	8.533	10.732	19.265
2015	30.814131	31.590	8.726	10.750	19.476
2016	30.913017	32.189	8.734	10.672	19.406
2017	30.990924	32.496	8.867	10.640	19.507
2018	30.969121	32.414	8.865	10.611	19.476
2019	30.901417	32.223	8.890	10.579	19.469
2020	30.389578	32.108	9.171	10.005	19.176
2021	30.790002	33.476	9.932	10.275	20.207
2022	31.548899	33.476	9.046	10.277	19.323

* This excludes other levies such and employee and employer NI contributions.
Source: OECD (2023b): https://data.oecd.org/tax/tax-revenue.htm

4.2 Definitions of the Tax Wedge in the literature

This section presents an overview of how tax wedges are defined in the literature most relevant to TAG A2.3, while Appendix A 2.1 examines other literature related to the origins, and closely related to definitions, of tax wedges. In TAG A2.3, equations 2, 3, 4, and 6 incorporate tax wedges (τ_1, τ_2, τ_3) to estimate net earnings for workers. Specifically, τ_1 is used in equations 2 and 3 to gauge the labour supply impact of the alternative transport scenario and in equation 3 as an alternative to τ_3 for assessing the broader implications of M2MLPJ. This tax wedge aligns closely with the definitions provided by Deskar-Skrbic et al. (2018) and OECD (2023a). It excludes considerations of (a) forgone unemployment benefits for new workers and (b) increased operating surplus due to productivity enhancements among existing workers.

The concept of the tax wedge is extensively discussed in the literature. Notably, Heinesen (1999) delves into a micro-founded analysis that underscores three different viewpoints to examine the tax wedge. Firstly, there is a perspective that evaluates all compensated (paid for) services and those compensated services that are taxable in comparison to the value of informal activities. As an example, the tax wedge's value can be discerned by comparing the extra financial strain in the formal labour market to its absence in the informal labour market. This arises because both the purchaser and provider can decide to split the tax savings in those cases where informal activities should have been taxes. Secondly, tax wedges can be used as metrics for economic inequality because they provide insights into the impact of taxes and social security contributions on income distribution and the financial incentives for work. Tax wedges measure the difference between employees; gross earnings and their net take-home pay after accounting for income taxes and social security contributions. Larger tax wedges mean workers keep a smaller portion of their gross earnings, which can affect disposable income levels and, consequently, income inequality. Lastly, Heinesen (1999) posits that the tax wedge can depict the duration an individual typically engages in the labour market to earn enough to counterbalance the costs of taxed services.

In their influential study, Deskar-Skrbic et al. (2018) build on existing micro-foundations of tax wedges in the literature, already reflected in the implementation within the equations of TAG A2.3 (DfT 2016, 2019). They too define any tax wedge as the disparity between the actual net compensation acquired by employees, also known as the real consumption wage, and the actual gross wage disbursed by employers, referred to as the real product wage. Their aim is to analyse the impact of taxation on employment in Croatia.

The micro-foundations-based definition of tax wedges were refined in a special OECD (2020) report[31] "How Tax Systems Influence Choice of Employment Form". According to this report, a tax wedge denotes the discrepancy between the labour costs borne by companies and the net income ultimately earned by employees. This discrepancy is determined by calculating the cumulative proportion of individual income tax, social security contributions from both the employee and employer, along with any relevant payroll tax, and then by deducting any state benefits. In the OECD study, these calculations give precedence to the determination of the net average tax rate for individuals. The concept of 'tax wedge' thus pertains to the computation of income tax and employee social security contributions, also considering adjustments for state benefits, relative to their gross earnings.

In Deskar-Skrbic et al. (2018), as well as in the OECD (2020) report, the primary analysis is centred on comparing tax wedges between a single employee without

[31] This is, in turn, based on Milanez & Bratta (2019).

dependents earning a median salary and single 'breadwinners' in families with two children, both with equivalent income levels. The OECD report highlights significant differences in the tax wedge across member nations in 2019. Countries such as Austria, Belgium, France, Germany, Hungary, and Italy recorded tax wedges exceeding 45%. In contrast, nations like Chile and New Zealand reported tax wedges below 20%. Belgium had the highest tax wedge at 52.2%, while Chile registered the lowest at 7.0%. On average, the tax wedge across the OECD was estimated to be 36.0%. The fundamental cause of the increases in tax wedges in other countries is attributable to tax reforms aimed at achieving higher income tax rates. This, however, was not the case for the UK. Updates to UK payroll seem to have been designed to be revenue and welfare neutral, including the payroll tax reforms in 2017.

Table 4.2 presents the OECD (2023) estimated tax wedges for the West European member states and the USA over the period 2000 to 2022. The same tax wedge estimates are illustrated in Figure 4.2. This provides a useful comparison to the estimated tax wedges for the UK. These tax wedges appear stable across time for all reported members. Member states with higher tax wedge rates tend to have rates that fall gently over time. Member states with lower tax wedge rates experience rates that fluctuate slightly but do not change systematically over these two decades.

Table 4.2: OECD % tax wedge estimates for selected West European countries and the USA, single person without children on average wage

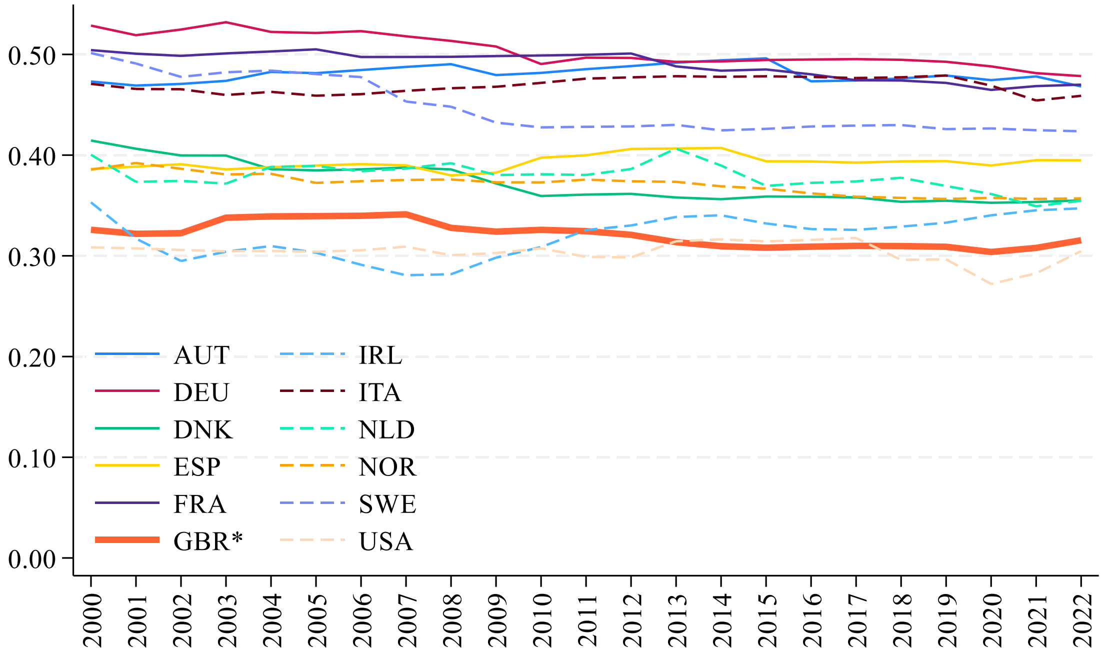
Year	AUT	DEU	DNK	ESP	FRA	GBR*	IRL	ITA	NLD	NOR	SWE	USA
2000	47.31	52.86	41.45	38.63	50.43	32.59	35.31	47.08	40.04	38.56	50.14	30.84
2001	46.91	51.91	40.64	38.86	50.07	32.19	31.71	46.57	37.35	39.22	49.10	30.74
2002	47.07	52.47	39.97	39.10	49.86	32.25	29.49	46.55	37.45	38.65	47.77	30.58
2003	47.38	53.20	39.96	38.58	50.11	33.79	30.42	45.97	37.17	38.09	48.23	30.46
2004	48.27	52.24	38.61	38.81	50.30	33.92	30.97	46.28	38.83	38.15	48.40	30.48
2005	48.14	52.13	38.49	38.97	50.51	33.94	30.32	45.90	38.92	37.24	48.05	30.42
2006	48.45	52.31	38.59	39.11	49.75	33.98	29.12	46.05	38.40	37.42	47.75	30.55
2007	48.76	51.80	38.77	38.99	49.75	34.12	28.08	46.39	38.67	37.54	45.32	30.92
2008	49.03	51.34	38.58	37.99	49.76	32.78	28.17	46.65	39.20	37.59	44.81	30.06
2009	47.95	50.79	37.19	38.26	49.84	32.41	29.82	46.79	38.02	37.30	43.23	30.28
2010	48.17	49.05	35.94	39.75	49.90	32.58	30.88	47.18	38.10	37.29	42.76	30.75
2011	48.54	49.68	36.08	39.99	49.96	32.46	32.56	47.60	38.03	37.57	42.81	29.91
2012	48.84	49.65	36.16	40.62	50.10	32.09	33.02	47.72	38.62	37.41	42.86	29.84
2013	49.18	49.26	35.79	40.66	48.81	31.36	33.86	47.84	40.65	37.35	43.01	31.45
2014	49.42	49.31	35.63	40.72	48.39	30.96	34.03	47.78	38.97	36.90	42.46	31.64
2015	49.62	49.45	35.89	39.39	48.51	30.81	33.22	47.83	36.95	36.68	42.61	31.44
2016	47.33	49.50	35.87	39.38	48.02	30.91	32.66	47.76	37.25	36.20	42.84	31.58
2017	47.42	49.54	35.81	39.26	47.44	30.99	32.58	47.66	37.40	35.88	42.93	31.78
2018	47.62	49.47	35.37	39.38	47.41	30.97	32.90	47.73	37.76	35.76	42.99	29.60
2019	47.90	49.27	35.47	39.41	47.17	30.90	33.29	47.91	36.94	35.65	42.58	29.66
2020	47.45	48.81	35.27	38.98	46.48	30.39	34.02	46.90	36.15	35.76	42.65	27.21
2021	47.82	48.14	35.35	39.50	46.86	30.79	34.53	45.43	34.93	35.65	42.48	28.27
2022	46.82	47.85	35.51	39.48	47.00	31.55	34.72	45.89	35.48	35.71	42.37	30.47

Source: OECD (2023b): https://data.oecd.org/tax/tax-wedge.htm

* GBR is the ISO code for the United Kingdom

Another feature of the data is that Norway (NOR) and the UK (GBR) underwent substantial revisions to their payroll tax system in 2017, but this was designed to be revenue-neutral and no substantial changes to the wedge are evident. In order to understand how the tax wedges map into the models and analyses in TAG A2.3, a more detailed review of the literature and the established intuitions is essential. This review is presented in the following subsections, beginning with average effective tax rates.

Figure 4.2: OECD Tax wedge estimates for selected West European countries and the USA, single person without children on average wage



Source: OECD (2023b): https://data.oecd.org/tax/tax-wedge.htm

* GBR is the ISO code for the United Kingdom

4.3 Tax policy and economic impact

The recent literature has focused on the broader consequences of tax reforms. These studies are typically directed at mapping tax reforms onto changes in aggregate tax revenue using macroeconomic general equilibrium models, and then simulating how this change in tax revenue affects economic growth, employment and welfare. Such studies are key to understanding and evaluating the intuition underlying the tax wedges in TAG A2.3 equations 4 and 6 on *wider impacts*. Given the distinct economic impacts of fiscal policy before and after the 2008 financial crisis, the literature is discussed in two separate subsections below.

4.3.1 Taxation and economic impact pre-2008

The world economy experienced sluggish growth and a general economic decline starting in 2004, which motivated extensive research on the macroeconomic impact of tax reforms. Within a theoretical framework, calibrated using values suggested by the empirical literature, Roeger (2007) examined the effects of taxation in the presence of distortions in the labour, capital and products markets within a rigid-prices, endogenous-growth model. By calibrating his theoretical model with parameter values based on the literature, his study indicated that

> labour taxes reduce both employment and growth, while capital taxes lower growth and have a non-negative employment effect. The paper shows that the market solution[32] leads to suboptimally low levels of growth and employment. However, available tax instruments are sufficient for the government to attain the first-best growth path in this economy. (Roeger 2007, page 24)

Blundell & Meghir (2002) presented an analysis of two distinct policy approaches that share a common purpose. The first approach involves the implementation of active labour market programmes, which encompass wage subsidies and enhanced job matching efforts. The second approach entails the provision of earned income tax credits, which serve to supplement the salaries of low-income families that are employed. While both strategies have common concerns regarding labour market incentives for low-skilled individuals, they often diverge significantly in other aspects. Their study provided an assessment of the effects of these two UK programmes aimed at improving the employment prospects of low-wage workers. These programmes shared numerous characteristics with other policy programmes in continental Europe or North America.

Before Blundell & Meghir (2002)'s study, Fiorito & Padrini (2001) utilised quarterly estimates of tax rates on consumption, capital, and labour for six OECD nations to assess the magnitude, direction, and timing of cyclical correlations between tax rate changes and labour market outcomes. They noted that high labour taxes can have a distorting effect on labour markets by influencing decision-making processes, thus contributing to the elevated unemployment rates observed in continental Europe. Nevertheless, it is important to note that while labour taxes may contribute to high unemployment rates, they are not the only factor influencing unemployment, as higher taxes can also lead to a reduction in the overall labour force, thus increasing the number of inactive adults. Their study provides initial structural evidence suggesting a negative relationship between labour taxation and employment growth. Similar incentive effects are captured in TAG A2.3 equations 2 and 3, where higher taxes are associated with lower gains in employment and GDP. Analogous disincentive effects that deter employment decisions are captured by Avi-Yonah (2000) in a model of tax disincentives to investment.

Leibfritz et al. (1997) investigated the theoretical and empirical literature pertaining to the influence of taxes on economic performance. In particular, their study focused

[32] By market solution, one means that the government only intervenes with taxes and allows markets to clear without any regulatory interventions, such as regulating work hours.

on the increasing integration of OECD capital markets that poses a constraint on the efficacy of employing tax incentives to stimulate domestic savings and investment. The implication of this integration was that the burden of taxation would likely shift towards labour, which is comparatively less mobile than financial capital as a factor of production. Their study suggested that greater labour market ‘flexibility’ would facilitate the transfer of the labour tax burden into reductions in real wages, hence reducing real labour costs. Blundell (1995) had previously come to a similar conclusion by focusing on the potential impact of tax reforms on work-hours and labour force participation.

4.3.2 Taxation and economic impact post-2008

The early years following the 2008 financial crisis were marked by economic recovery in GDP and employment from a low starting point, see ONS (2018). Fiscal policy and tax reforms during this period were aimed at boosting this recovery and the research focus was on exploring possible reforms. De Henau (2022) used post-2008 data to assess the anticipated economic and fiscal effects of a substantial annual public investment programme in universally-accessible, high-quality early childhood education and care (ECEC) programmes in the UK. He found that investing in high-quality universal ECEC yields significant benefits for all children, particularly large for those from economically disadvantaged backgrounds. Furthermore, it facilitates the advancement of gender equality in the workforce through the creation of a greater number of well-remunerated positions for women, surpassing the opportunities provided by traditional investment strategies such as construction sector projects. De Henau’s study focused on two potential funding alternatives for a programme to increase the state benefits paid to women with high fertility rates. In the first scenario a payback period of 21 to 31 years would be needed. This is a timeframe that falls within the usual span of a person's working life after the birth of their first child, typically around 35 years. In the second scenario, there would be an increase in the financial contribution from the wealthiest 20% of households, amounting to almost 0.4% of their total income, would be need. Both scenarios are relevant to the wider impacts captured by equations (4) and (6) of TAG A2.3 as they are aimed at assessing the long-term welfare gains or losses because these wider impact equations are one of the ways in which TAG A2.3 captures welfare changes.

The research of Korkmaz et al. (2022) follows in the spirit of King (1985) and Barro & Sahasakul (1983), and demonstrates that governments possess the capacity to enact diverse policies to attain their desired economic objectives. Since tax revenues are a fundamental component of fiscal policy, tax revenue fluctuations have the potential to exert both direct and indirect impacts on economic growth in the post crisis period, operating through a range of channels. Their study examines the relationship between tax revenues and economic growth from 2010 to 2019 for the UK and eight other OECD countries.

Implementing non-linear, progressive income taxation as a means to address the post crisis economic recovery has been more recently examined by Hansen (2021) for the US. The model in this study considers labour supply responses at both the intensive (hours and effort) and extensive (participation) margins. The ideal configuration for an Earned Income Tax Credit (EITC) entails the integration of negative marginal taxes and negative participation taxes within the lower tiers of the income distribution. As outlined in Hansen (2021), the best design to implement non-linear labour taxation is shaped by two conditions. Firstly, the decrease in the semi-elasticities of labour participation as income grows. Secondly, a modest social concern for income redistribution from the poor to the very poor. The final result is impacted by a previously disregarded trade-off between distortions associated with the level of economic activity and distortions associated with the magnitude of economic activity. This trade-off notably involves the balancing of two efficiency variables. Based on numerical simulations, Hansen proposes that a significant enlargement of the Earned Income Tax Credit (EITC), with a specific focus on adults without children in the United States, might potentially augment overall well-being.

The macroeconomic impact of post-crisis discretionary tax reforms on employment in the EU is examined by van der Wielen (2020). This study presents initial panel estimates of output and employment multipliers for tax changes. The numerical simulations suggest that the observed employment responses exhibit an increase of up to one percentage point. Within the EU, evidence has been found regarding the presence of asymmetries in the impact of policies aimed at raising and decreasing revenue.

A similar approach, albeit with a different methodology, is adopted by Szarowska (2014) who examined the significance and disparities associated with personal income taxation within the context of a tax framework. Her study inspected the taxes of individual workers in 21 European countries, specifically focusing on OECD and EU member states. She found that personal income taxes played a substantial role in both the financial aspect of public funds and the impact they have on various government policies and objectives. Thus, personal taxes are an important component in the analysis of wider economic impacts, including the impact on employment and welfare as modelled in equations 1 to 6 of TAG A2.3.

5 The impact of using revised TAG A2.3 labour parameters

Key points: This section presents the link between the TAG A2.3 equations and the Wider Impacts of Transport Appraisal (WITA) software. It also presents a calibration exercise examining the implications of changing the four parameters under review.

5.1 Simple, useful transformations for equations 2, 3 and 4

TAG A2.3 equations 2 and 3 can be re-arranged to produce equations 2a and 3a, presented here. These transformations highlight that both the elasticity and the tax wedge can be positioned as a fraction outside the summation terms. Equations 2a and 3a simplify the process of assessing the impacts of changing ε^{LS} or τ_1. All one has to do is compute the value of $\varepsilon^{LS}/(1-\tau_1)$ under various combinations of ε^{LS} and τ_1 to easily compare the scale effects of altering their values. For instance, under current assumptions in TAG A2.3 this ratio equals:

$$\begin{aligned}\frac{\varepsilon^{LS}}{1-\tau_1} &= \frac{0.10}{1-0.30}\\ &= 1/7\\ &\approx 0.142857\end{aligned}$$

Equation 2a: Labour Supply/Employment Impact
$$\Delta E^f = \frac{\varepsilon^{LS}}{1-\tau_1}\Omega\sum_i\left[\left(\frac{\sum_j (G_{i,j}^{B,f} - G_{i,j}^{A,f})W_{i,j}^f}{\sum_j y_j^f W_{i,j}^f}\right)\sum_j W_{i,j}^f\right], \quad \forall f$$
Equation 3a: GDP impact [of employment changes]
$$\begin{aligned}\Delta GDP^f &= \frac{\varepsilon^{LS}}{1-\tau_1}\eta\Omega\sum_i\left[\left(\frac{\sum_j (G_{i,j}^{B,f} - G_{i,j}^{A,f})W_{i,j}^f}{\sum_j y_j^f W_{i,j}^f}\right)\sum_j y_j^f W_{i,j}^f\right], \quad \forall f\\ &= \frac{\varepsilon^{LS}}{1-\tau_1}\eta\Omega\sum_i\sum_j W_{i,j}^f (G_{i,j}^{B,f} - G_{i,j}^{A,f})\end{aligned}$$

Using Equation 3a simplifies the process of solving TAG A2.3 equation 4 under various scenarios. This is achieved y including the tax wedge τ_2 as a coefficient alongside the ratio $\tau_2\varepsilon^{LS}/(1-\tau_1)$ for equation 3a.

An earlier variant of equation 3a was suggested for TAG A2.3 in DfT (2014, page 31, equation 4.1a) whereby "Given equation 4.2a [$m_j^f = \eta y_f^f$], equation 4.1 simplifies to"

$$GP1^f = -\varepsilon^{LS}\frac{\eta}{1-\tau_1}\sum_i\left(\sum_j W_{i,j}^f (G_{i,j}^{A,c,f} - G_{i,j}^{B,c,f})\right)$$

The only difference between equation 3 in DfT (2019, 2016) and equation 4.1a in DfT (2014) is the absence of Ω in the latter. This is because Ω is unnecessary in equation

4.1 given $G_{i,j}^{A,c,f}$ and $G_{i,j}^{B,c,f}$ are the generalised commuting costs per year. The c superscripts simply indicate they are commuting costs but also help us differentiate them from daily commuting costs ($G_{i,j}^{A,f}$ and $G_{i,j}^{B,f}$) in later TAGs. Conversely, in equation 3 of DfT (2019, 2016) $G_{i,j}^{B,f}$ and $G_{i,j}^{A,f}$ are the commuting costs per day and Ω is necessary as it is the average annual number of round-trip commuting journeys.

TAG equation 4 is a simple extension of equation 3, and it can be re-parameterised by specifying equation 4a, with $\tau_2\varepsilon^{LS}/(1-\tau_1)$ outside the summation. It can also be specified by replacing $\tau_2 = \tau_1 + \tau_B$ as previously illustrated in equation 4alt.

Equation 4a: Wider Impacts 1 - Tax Wedge

$$WI_{LSI}^{f} = \frac{\tau_2\varepsilon^{LS}}{1-\tau_1}\eta\Omega\sum_i\sum_j W_{i,j}^{f}(G_{i,j}^{B,f} - G_{i,j}^{A,f})$$
$$= \frac{(\tau_1+\tau_B)\varepsilon^{LS}}{1-\tau_1}\eta\Omega\sum_i\sum_j W_{i,j}^{f}(G_{i,j}^{B,f} - G_{i,j}^{A,f})$$

Though the parameters under review are not included in TAG A2.3 equation 5, equation 6 combines equation 5 with the tax wedge for existing workers $\tau_3(=\tau_1)$ as a scaling coefficient. This structure facilitates the evaluation of the impact of changing this tax wedge on equation 6, especially regarding the broader effects on existing workers M2MLPJ.

5.2 The WITA simulation software

This section serves to illustrate the link between the TAG A2.3 model specification and the WITA software implementation. It also shows that the WITA software's operationalisation of equations 3 and 4 is based on the transformations illustrated in equations 3a and 4a. These transformations streamline the computations in the simulations.

Functional aspects of the WITA simulation software are presented in the DfT (2018) “WITA Version 2.0 Software Requirements Specification”. The WITA method for implementing equation 1 is described in DfT (2018, section 5.3.1). Equation 2a is not explicitly presented in WITA but is a sub-specification of 3a without the wage effects.

The WITA analogue to equation 3a is presented in DfT (2018, section 5.3.2.1) with a change to the notation[33] and the summation only over the home districts I:

[33] In this WITA equation the following substitutions are made to the notation in equation 3a is: $I = i$, $J = j$, $y = f$, $\sigma = \tau_1$, $PR = \eta$, $ann = \Omega$, $DHTW_{IJ}^{1j} = W_{i,j}^{f}$, $\text{AGC\_Commute\_PA}_{IJ}^{0y} = G_{i,j}^{B,f}$ and $\text{AGC\_Commute\_PA}_{IJ}^{1y} = G_{i,j}^{A,f}$.

$$LS_J^y = \frac{\varepsilon^{LS}}{1-\sigma} \times PR \times ann \sum_I DHTW_{IJ}^{1y} (\text{AGC\_Commute\_PA}_{IJ}^{0y} - \text{AGC\_Commute\_PA}_{IJ}^{1y})$$

where the proposed simplification to the minus signs in equation 3 is applied here too. The total labour supply impact is then calculated by summing LS_J^y across the workplace districts J.

The implementation of equation 4 for the wider impacts of labour supply effects is presented in DfT (2018, section 5.3.2.2) as equation:

$$\text{Welfare\_LS}_J^y = \text{LStax} \times \text{LS}_J^y$$

with notation changes where LS_J^y replaces LS_I^y, and $\text{LStax} = \tau_2$ is the labour supply tax wedge that includes savings due to not paying unemployment benefits. These are simple calculations if one has the results from the previous equations in hand.

TAG A2.3 equation 5 is not affected ty the parameters under review in this report. For completeness, its treatment in DfT (2018) is included here. TAG A2.3 equation 5 without the summation across areas j, replacing j with I, replacing f with y, A with 1 and B with 0 gives:

$$\Delta GDP_{M2MLPJ,I}^y = GDPW^{0y} PI_I (E_I^{1y} - E_I^{0y})$$

In DfT (2018, section 5.4.1) "[t]he GDP impact of labour productivity effects is given by" with a slight notation change as:

$$\Delta GDP_{M2MLPJ,I}^y = \left[GDP^N \prod_{x=base\ year+1}^{y} (1 + gGDPW^x) \right] PI_I^y \left(E_I^{1y} - E_I^{oy} \right)$$

where one can see that the WITA equation above is more explicit about the evolution across time of

$$GDPW^{0y} = GDP^N \prod_{x=base\ year+1}^{y} (1 + gGDPW^x)$$

where GDP^N is the "is the base year average national GDP per worker", and "$gGDPW^x$ is the Growth in GDP defined in the GDPw_GROWTH table of the Global Data file (see section 3.11.1.2)".

The implementation of equation 6 for the wider impacts of labour productivity effects is presented in DfT (2018, section 5.4.2), with a notation change, as the equation:

$$\text{Welfare\_LP}_I^y = \text{LPtax} \times \Delta GDP_{M2MLPJ,I}^y$$

where $\Delta GDP_{M2MLPJ,I}^y = \text{LP}_I^y$ and $\text{LPtax} = \tau_3 (= \tau_1)$ is the labour productivity tax. These too are simple calculations if one has the results for equation 5 at hand.

DfT (2018, section 5.5) describes how values across the forecast years $y = f$ are generated. It describes how "WITA accepts data for up to six modelled years and it will, therefore, need to interpolate/extrapolate benefits and changes in expenditure for all the other years within the appraisal period." In practice, only two years need be modelled in WITA. The guidance goes on to describe "that linear-based interpolation is undertaken up to the last modelled year whilst horizontal-based extrapolation is thereafter."

5.3 The impact of using alternative parameter values

Herein a simple exercise is presented to evaluate the impact of changing the parameters under review in this project. The validity of the exercise has been verified by simulations using the WITA v2.3 software. Assume a proposed transport investment project is forecast to generate the modest net discounted present values described below, at 2010 prices across the years 2030 to 2089.

Based on TAG A2.3 equation 3, the investment is forecast to generate the following labour supply impact on GDP. If the ratio described in equation 3a is factored out and the existing parameter values are applied:

$$\begin{aligned} \Delta GDP_{LSI}^{f=2030:2089} &= \frac{\varepsilon^{LS}}{1-\tau_1} X_{LSI} \\ &= \frac{0.10}{1-0.30} \times 700,000 \\ &= 100,000 \end{aligned}$$

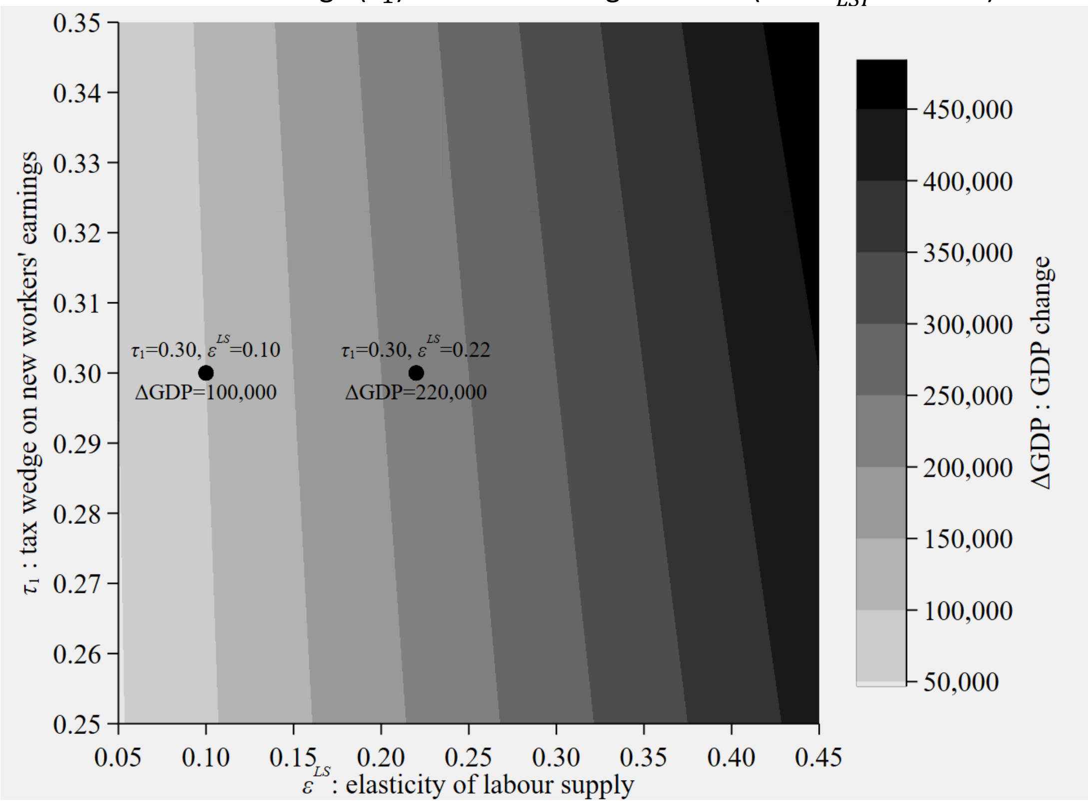
A representative range of parameter values are chosen to illustrate their impact on the assessment of this investment in Figure 5.1. Based on the literature review in Section 4, a tax wedge τ_1 with a mid-value of 0.30 and a range of 0.25 to 0.35 in the vertical axis seems reasonable. Based on the literature review in Section 3, a labour supply elasticity ε^{LS} with a range of 0.05 to 0.45 spans all viable values on the horizontal axis. Figure 5.1 illustrates all values using shading for the net discounted present change in GDP based on the equation:

$$\Delta GDP_{LSI}^{f=2030:2089} = \frac{\varepsilon^{LS}}{1-\tau_1} \times 700{,}000$$

Figure 5.1 shows that the small range of suggested values for the tax wedge τ_1, on the earnings of new workers, has a minimal impact on net GDP changes. The proposed change in the elasticity of labour supply is much greater. For instance, if this were changed from the current $\varepsilon^{LS} = 0.10$ to a proposed $\varepsilon^{LS} = 0.22$, the estimated net benefit would be:

$$\begin{aligned} \Delta GDP_{LSI}^{f=2030:2089} &= \frac{\varepsilon^{LS}}{1-\tau_1} X_{LSI} \\ &= \frac{0.22}{1-0.30} \times 700,000 \\ &= 220,000 \end{aligned}$$

Figure 5.1: Surface graph for impact of labour elasticity (ε^{LS}) and new workers' tax wedge (τ_1) values on changes in GDP ($\Delta GDP_{LSI}^{f=2030:2089}$)



Turing to the effect of labour tax wedges, to simulate the effect on the wider labour supply impacts captured by equation 4, if the tax wedge on new workers' earnings is kept at the presently used value of $\tau_1 = 0.30$ the wider impacts of this particular transport investment project are:

$$
\begin{aligned}
WI_{LSI}^{f=2030:2089} &= \tau_2 \frac{\varepsilon^{LS}}{1-\tau_1} \times 700{,}000 \\
&= 0.40 \times \frac{0.10}{1-0.30} \times 700{,}000 \\
&= 40{,}000
\end{aligned}
$$

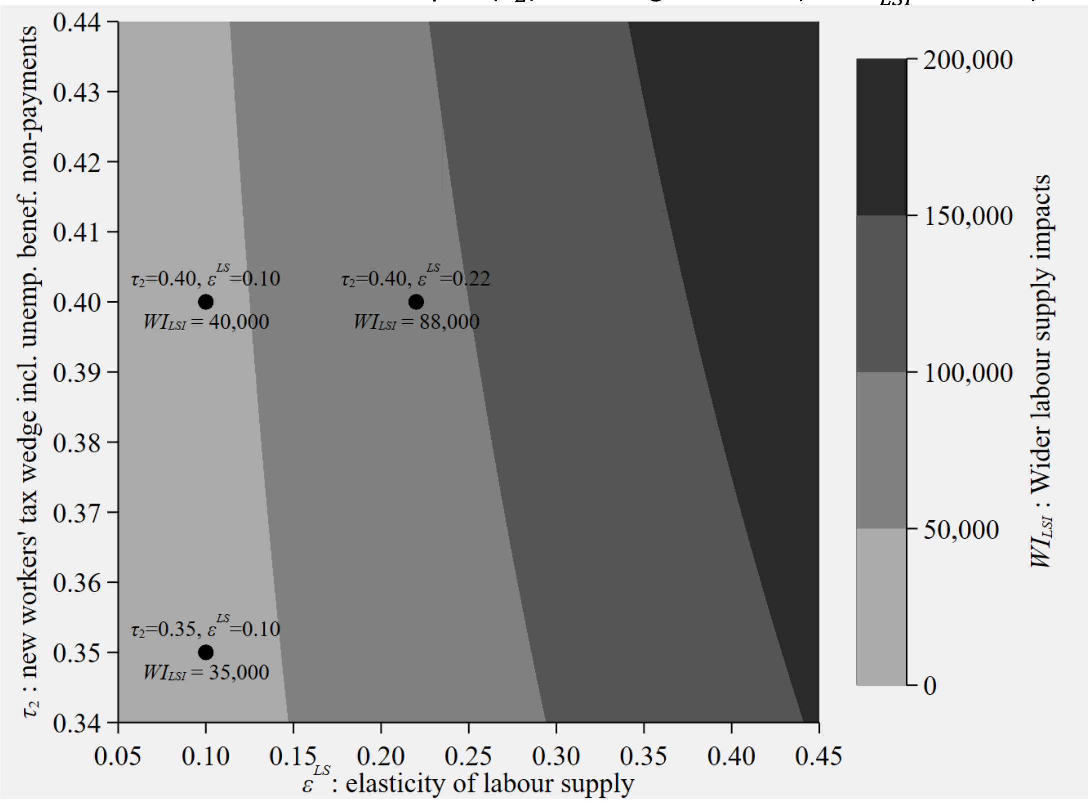
Figure 5.2 illustrates various estimated values of the labour supply wider impact $WI1$ for different labour supply elasticities ε^{LS} and various values of the tax wedge τ_2 that includes savings on not paying out-of-work benefits to newly employed workers. Altering the value of the τ_2 and ε^{LS} parameters independently of one another has a linear impact on variations to the forecast wider impacts, as both parameters appear in the numerator of equation 4a. Changing the two parameters in combination has small non-linear effects. The presently used $\tau_2 = 0.40$ possibly needs little revision. Even a substantial reduction by 0.05, by removing half of savings from out-of-work non-payments, would have little effect on this estimated wider impact:

$$
\begin{aligned}
WI_{LSI}^{f=2030:2089} &= 0.35 \times \frac{0.10}{1-0.30} \times 700{,}000 \\
&= 35{,}000
\end{aligned}
$$

Also illustrated in Figure 5.2 are the wider impacts for this simulation when the presently used $\tau_2 = 0.40$ is combined with the proposed elasticity of $\varepsilon^{LS} = 0.22$:

$$WI_{LSI}^{f=2030:2089} = 0.40 \times \frac{0.22}{1-0.30} \times 700,000$$
$$= 88,000$$

Figure 5.2: Surface graph for impact of labour elasticity (ε^{LS}) and tax wedge for remittances to the exchequer (τ_2) on changes in GDP ($\Delta GDP_{LSI}^{f=2030:2089}$)



The final example is not illustrated graphically as it is simply a linear function of only one of the parameters under review. Equation 6 for the wider impacts of existing workers M2MLPJs depends on equation 5 and only on the tax wedge for existing workers $\tau_3(=\tau_1)$. Assume that under the presently used values, for this hypothetical transport investment project, its value is:

$$WI_{M2MLPJ}^{f=2030:2089} = \tau_3 \Delta GDP_{\text{M2MLPJ}}^{f=2030:2089}$$
$$= 0.30 \times 200,000$$
$$= 60,000$$

Changes to the tax wedge $\tau_3(=\tau_1)$ have simple linear effects on the estimated wider impacts. Furthermore, this parameter seems in line with current estimates in the literature. Even if τ_3 is decoupled from the tax wedge τ_1 on new workers because of changes in the tax system, it is unlikely to deviate substantially from the latter.

6 Summary and future research

Key points: This project was tasked with using the extant research literature to review the values of four parameters used by the DfT in its Transport Analysis Guidance (TAG) to assess the employment effects of proposed transport infrastructure investments. The review in Section 2 indicates that the labour supply elasticity with respect to wage changes (ε^{LS}= 0.10) is currently too low and if re-estimated likely to be closer to 0.22, or possibly higher. The review in Section 3 indicates that the two presently used labour tax wedges on new and existing workers (τ_1= τ_3= 0.30) concur with current OECD estimates of around 0.30.[34] The tax wedge, which accounts for savings from not paying unemployment benefits, needs further evidence to support its current value. However, it seems unlikely that it would deviate substantially from its presently used value (τ_2= 0.40).

Section 2 contextualises the use of these four parameters within six equations in the TAG A2.3 (DfT 2019, 2016, 2014, 2005). The discussion therein suggests ways in which the DfT may choose to revise and streamline the equations' notation and the terminology. It also suggests that the tax wedge on new workers (τ_1) ought to be de-coupled from the tax wedge on existing workers ($\tau_3 \neq \tau_1$) but both be kept at 0.30 until new evidence becomes available. Documentation for the WITA software (DfT 2018) should be revised and streamlined in a similar way. One aim should be to align the notation in the WITA software guidance to the notation in TAG A2.3. Given WITA is an exact software implementation of the theoretical underpinnings provided in TAG A2.3, it would facilitate dissemination if the notation in the two matched each other.

Section 3 focuses on reviewing the literature on estimates of the elasticity of labour supply with respect to wage changes. It finds that the literature in this area is either dated or it focuses on specific population groups. For instance, early literature in the 1970s focused on the labour supply of men. The literature thereafter has focused on the labour supply of women. In more recent years the focus has been more specific, such as concentrating on single mothers or nursing staff. What evidence there is on the labour supply elasticity for new workers, i.e. the *extensive margin*, suggests its value for the UK is closer to $\varepsilon^{LS} = 0.22$ than the presently used ε^{LS}=0.10 in TAG A2.3. The literature indicates the range for this elasticity in the UK is from 0.15 to 0.43. Future research could be carried out on a population-representative microeconomic dataset, such as the UK Labour Force Surveys, to estimate the (extensive margin) labour supply elasticity of workers entering and exiting employment. For completeness, the same research could also determine the (intensive margin) labour

[34] To recap, the denominator in these tax wedges is all labour costs, including: net wages, cash transfers (e.g. child benefits), employee NI contributions, employer NI contributions, and (starting in 2017 for the UK) payroll taxes.

supply elasticity of existing workers could also be estimated in case this needs to be incorporated into DfT modelling.

Section 4 provides an extensive review of the theory underlying definitions of labour tax wedges. Much of the empirical evidence in this section is based on calculations by the OECD (2023a, 2023b). These indicate that the presently used TAG A2.3 labour tax wedges for newly employed workers and existing workers who M2MLPJ (τ_1=τ_3=0.30) seem consistent with existing estimates in the literature. The labour tax wedge that also includes savings from non-payment of unemployment benefits to new workers seems reasonable in magnitude (τ_2=0.40) but a dedicated study on this would be useful. This could be included in a wider study of all three labour tax wedges to verify their currently used values. It is recommended that this study be carried out once UK price inflation returns to approximately the 2% Bank of England target. The reason for this is that income tax thresholds may not move entirely in line with price inflation, in a process commonly known as *fiscal drag* or *bracket creep*. Estimating the tax wedges during periods of low and stable price inflation should provide values that are valid in the long-term.

Section 5 includes simple calibration exercises to explore the implications of changing these parameters for a hypothetical transport investment project. This exercise shows that changing the tax wedge parameters has a modest impact on the estimated net benefits of investment projects. This is because current tax wedges do not seem to need much adjustment, if any. The presently used labour supply elasticity (ε^{LS}= 0.10) seems low compared to most recent estimates. Re-calibrating it to a value closer to a mean of recent estimates ($\varepsilon^{LS} = 0.22$) implies that the modest net employment effects associated with people gaining, or losing, employment are greater (see equations 3 and 3a). The net employment effect on GDP changes carries over onto the wider labour supply impacts by the same proportion as the change in the elasticity (see equations 4 and 4a).

7 References

References are split into three sections: general subject-area ones, labour supply elasticities, and labour tax wedges.

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Appendices

A1.1 Why not allow the level of unemployment to change?

Choosing not to change the *level* of unemployment might have been influenced by macroeconomic theories such as the natural rate of unemployment (NRU) and the non-accelerating inflation rate of unemployment (NAIRU), which became popular in the 1970s and 1980s. Paragraph 2.2.6 in DfT (2016, 2019) provides an overview of this philosophy:

> In keeping with HM Treasury (2022) Green Book guidance, the economy is assumed to operate at full employment in the long run, such that only transport investments which increase the supply of labour can increase the number of jobs at the national level. In the absence of labour supply impacts, changes in the demand for labour will lead to 100% displacement of employment at the national level; employment would be displaced from other industries or locations. The implications for transport appraisal are as follows:
>
> 1. Transport investments which induce changes to the national supply of labour have employment effects at both the local and national levels. The extent of the increase in net employment will depend upon the demand response to the increase in the supply of labour.
> 2. Transport investments which affect the distribution of labour demand, in terms of industry or location, but which do not lead to a change in the national supply of labour can have employment effects in terms of number of jobs at the local but not the national level.

However, neither we nor TAG A2.3 tackle the difference between levels and rates of unemployment. This distinction arises because, unlike other labour ratios, the unemployment rate's denominator includes only the number of people employed and unemployed, but excludes the labour-market inactive. TAG A2.3 does not mention unemployment *rates*. Maintaining a constant unemployment rate while employment is increasing would be challenging, as it would require the number of unemployed individuals to increase as well.

Having said all this, paragraph 2.2.8 in DfT (2019, 2016) offers the possibility that, in exceptional circumstances, changes in the levels of unemployment might be affected by transport investment:

> In exceptional circumstances, the local economy may temporarily operate below full employment, which a transport investment could potentially help to relieve. If this is considered to be the case, the

scheme promoter needs to provide the following information in the Economic Narrative: (1) present context specific evidence which demonstrates the local economy is operating below full employment; (2) determine the length of time before the economy would be expected to return naturally to full employment; (3) justify why the particular transport investment is expected to reduce unemployment; (4) determine the persistence of the new jobs; (5) explain how these impacts are to be quantified and valued.

A1.2 Differences in equations 2 & 3 between DfT (2019) & DfT (2016)

In DfT (2016) equations 2 and 3 differ in how the summations are carried out compared to DfT (2019, 2014), leading to slightly different results. In DfT (2019) these summations returned to what they were in DfT (2014). Applying our notation changes, DfT (2016) equation (2) is:

$$\Delta E^{f} = \sum_{i} \sum_{j} \left[\varepsilon^{LS} \left(\frac{\sum_{j} (G_{i,j}^{B,f} - G_{i,j}^{A,f}) \Omega}{(1-\tau_1) y_j^f} \right) W_{i,j}^{f} \right] \quad \text{(DfT 2016, eq. 2)}$$

Applying our notation changes, DfT (2016) equation (3) is:

$$\Delta GDP^{f} = \sum_{i} \sum_{j} \left[\varepsilon^{LS} \left(\frac{\sum_{j} (G_{i,j}^{B,f} - G_{i,j}^{A,f}) \Omega}{(1-\tau_1) y_j^f} \right) \eta GDPW_j^{f} W_{i,j}^{f} \right] \quad \text{(DfT 2016, eq. 3)}$$

where in DfT (2016) the second y_j^f is replaced with $GDPW_j^{S,f}$, representing the GDP of the average worker in area j, in year f, under scenario S.

A2.1 Effective tax rates

A key tool to understand labour tax wedges and their application in TAG A2.3 models is the effective tax rate (ETR) on labour.[35] Two seminal studies that present a detailed account of the ETR are Mendoza et al. (1994) and Carey & Tchilinguirian (2000). While the estimates of the ETR for the G7[36] are discussed in Mendoza et al. (1994), Carey & Tchilinguirian (2000) update these estimates on capital, labour, and consumption for most OECD countries.

[35] Often the distinction is made between the Effective Tax Rate (ETR) and the Average ETR (AETR). The ETR measures the amount of tax paid as a percentage of the taxable income or profit, after accounting for deductions, exemptions, and other tax preferences. Thus, ETR provides insights into the rate of taxation applied to each additional unit of income. AETR measures the average rate of taxation on total income, considering all deductions, exemptions, and adjustments. It is calculated by dividing the total tax paid by the total taxable income. Thus, AETR gives a broad overview of the tax burden, reflecting the overall percentage of income or profits that is paid in taxes.

[36] The G7 includes Canada, France, Germany, Japan, Italy, the UK and the US.

The methodology applied in Carey & Tchilinguirian (2000) incorporates modifications to some underlying assumptions to enhance their logical coherence. While some of these are not directly relevant to the current study, the modifications deserve to be highlighted before explaining the TAG A2.3 effective tax wedges. In Carey & Tchilinguirian (2000), the Mendoza et al. (1994) assumption that all self-employment revenue is capital income is abandoned in favour of the assumption that self-employed people also earn labour income. This adjustment significantly lowers the projected ETR on labour and increases estimates of the AETR on capital. Though ETR levels differ, temporal national trends seen in Mendoza et al. (1994) are confirmed in the Carey & Tchilinguirian (2000) results.

Though not directly relevant to the TAG A2.3 analysis, the revised Carey & Tchilinguirian (2000) estimates of indirect AETRs for OECD countries do not align with those identified in Mendoza et al. (1994). The updated estimates indicate that most OECD countries have directed the rise in the tax burden towards labour. According to Carey and Tchilinguirian (2000), the UK is in contrast to other countries as it has recorded a steady AETR on both direct and indirect taxes up to 1999. However, it is important to note that both the Mendoza et al. (1994) and Carey & Tchilinguirian (2000) estimates may understate the AETRs in countries when considerable revenues are received via resource taxes on natural resources.

Thus, Carey and Tchilinguirian (2000) provide a critique of Mendoza et al. (1994). Firstly, the Mendoza et al. (1994) technique focuses on comparing realized tax collections with the assumed tax base on earnings, ignoring shifts in the tax burden across sources or groups (e.g. due to child benefits). The data used in Mendoza et al. (1994) on tax collections is sourced from the OECD Revenue Statistics, which includes time series of various tax revenue streams. The estimated values of these tax bases are derived from national accounts. However, to align the data sets, several assumptions must be made. This includes how to deal with a common problem with household taxes where the taxes paid on capital and labour income are not differentiated. In order to tackle this issue, Mendoza et al. (1994) make the simplifying assumption that households face equivalent effective tax rates on both capital and labour earnings. This assumption, however, may not hold for most OECD countries, including the UK.

Secondly, the Mendoza et al. (1994) equations include potential flaws in their treatment of social security, a feature directly relevant to TAG A2.3 estimates of effective tax wedges. In Mendoza et al. (1994, equation 3), employees' contributions are counted twice in the numerator for the ETR on labour τ_l,

$$\tau_l = \frac{q_l(e_l - h_l) - p_l(e_l - h_l)}{q_l(e_l - h_l)}$$

where q_l is the is the producer pre-tax price (wage) of labour, p_l is the consumer post-tax price (wage) for labour, e_l is the time endowment of labour, and h_l is the time allocated to leisure. Thus $e_l - h_l$ is labour supply and, furthermore the equation above simplifies to $\tau_l = (q_l - p_l)/q_l$. Additionally, the denominator of their equation (3) does not reflect the fact that households can deduct social security contributions from taxable income. Social security contributions that cannot be allocated to employees, employers, or the self-employed are all assigned to labour, despite being paid from both capital and labour income. Self-employed contributions are included in total contributions in equation (3) while all self-employed income, including social security contributions, is allocated to capital in equation (4). The paper by Mendoza et al. incorporates these taxes into household and/or company tax sections. Their study also omitted property taxes, including wealth taxes, estate, inheritance, and gift taxes, which can be seen as additional charges on capital income. These are revised accordingly in Carey and Tchilinguirian (2000).

A2.1.1 Other estimates of effective and marginal tax rates

The study by Lehmann et al. (2013) examines the correlation between gross labour income and marginal and average net-of-tax rates in France for the period 2003 to 2006. Their study exploits a deliberate change to the income-tax and payroll-tax systems, targeting all persons with earnings below twice the minimum wage. Lehmann et al. find the estimated elasticity of gross labour income with respect to the marginal net-of-income-tax rate is roughly 0.20, but no noticeable reaction is found with respect to the marginal net-of-payroll-tax rate. Their income-tax schedule does not display a substantial degree of responsiveness in relation to changes in the average net-of-tax rate, whereas the payroll-tax schedule has a strong negative correlation with respect to the net-of-tax rate, approaching -1. One plausible explanation for this can be attributed to the existence of significant labour supply responses to the income tax system, together with enduring posted wages (i.e., the overall labour income less payroll taxes divided by the number of hours worked). In conclusion, they suggest that the influence of the net-of-income-tax rate is predominantly shaped by decisions pertaining to participation, particularly among married women.

In line with Lehmann et al. (2013), Simkovic (2015) clarifies that since payroll taxes are levied on either employers or employees, and are often calculated as a percentage of the compensation that employers provide to their employees, who bears the tax does not significantly alter its economic impact. However, when these taxes are applied exclusively to wages and not to profits from financial or physical investments, it can hinder the allocation of resources towards the development of human capital, particularly in areas such as higher education. Following this intuition, one might assume that even though the OECD estimate of the 30.9% UK effective tax rate is largely unaffected by the 2017 payroll tax reforms, evaluating the ultimate impact of these reforms on human capital and the incentive to work may require a longer sample.

Before the work of Carey and Tchilinguirian (2000) and Mendoza et al. (1994), Visser & Saunders (1986) provided early estimates of marginal tax rates on capital and labour in OECD countries using primary tax legislation as data. Their study aimed to gauge the build-up of taxes at the marginal rate, as governments considered adjustments to their tax systems in light of concerns about the detrimental effects of high tax rates in OECD countries. The main focus of their research lies in the aggregation and interplay of individual taxes, arguing that a mere examination of individual taxes does not capture the combined effect of these taxes on private decisions, such as labour supply. Their study suggests that the outcomes of consumption tax rates and social security rates can be similar. For TAG A2.3 estimates of effective tax wedges, these considerations might influence the estimated values of the τ_1 and τ_2 tax wedges.

Fullerton (1984) shows that it's possible to determine an effective tax rate for capital gains based on either average or marginal income, by considering whether it solely includes corporate taxes. The study categorizes effective tax rates into four primary groups and discusses eleven distinct reasons why the effective tax on a marginal investment might differ from that on a prior or average investment. However, the study does not specifically address if and how such changes in the effective capital tax rate might influence the effective labour tax rate.

The study by Fullerton (1984) builds on that of Joines (1981), which provides a concise overview of the methodology employed to ascertain the effective tax rates on labour and capital revenues inside the United States. Their approach applied to data spanning the period 1929 to 1975 involved the calculation of annual estimates for factor income tax rates.

A2.1.2 Economic impact and estimates of effective and marginal tax rates

There are important studies that address the implications of effective and marginal tax rates due to tax reforms, and how revised tax wedges can explain changes in key economic indicators. Disney & Smith (2002) demonstrate that individuals are deterred from engaging in the workforce due to the presence of elevated effective labour tax rates, especially when they are close to the state pension age. The UK, having abolished its pension 'earnings rule' in 1989, presents a noteworthy case study for examining the consequences of a policy that eliminated penalties on the state pension for those who continue to work beyond the state pension age.

Disney & Smith (2002) examine the probable consequences of similar pension reforms, while also considering the potential implications for the deferral of pension entitlements. The abolition of similar regulations in the US resulted in a notable rise of almost four work hours per week, on average for older male employees, while having a comparatively lower impact on the work hours of female employees. Their study is therefore an important contribution to the literature that addresses how changes in effective tax rates map onto changes in employment.

Evers et al. (2015) examine 12 European countries that have implemented Intellectual Property (IP) Box regimes, which offer significantly lower company tax rates for income generated from innovations in intellectual property. They argue that, in these countries, there is an essential need to adjust the methods used to calculate the cost of capital and the effective average tax rate. Thus, any tax reform that alters the factor allocation incentives necessitates revising the AETR estimates, and thereafter reassessing the implications on key economic variables. According to Evers et al. (2015), the treatment of expenses associated with IP income is essential in determining the actual aggregate tax burden. However, deducting expenses at the regular corporate income tax rate instead of the reduced IP Box tax rate can lead to negative effective average tax rates, potentially subsidizing unproductive initiatives, which may include employing labour resources that might be better deployed elsewhere. Evers et al. (2015) therefore explore the potential effects of IP Boxes on business decisions and policy objectives, with some focusing on income streams connected to intellectual property and others attaching the tax benefit to actual actions. Though not directly relevant to the labour tax wedges considered in TAG A2.3, their study highlights the importance of embedding important reforms in reassessing labour tax wedges.

In an earlier study, King (1985) demonstrated that governments, by means of monetary and fiscal policies, possess the ability to enact diverse reforms in order to attain their desired economic objectives. According his study, tax revenue fluctuations can have a direct or indirect impact on economic growth through multiple channels, and one of the key determinants for measuring changes in tax revenues is the changes in effective and marginal tax rates. Prior to this study, Barro & Sahasakul (1983) found that the impact of taxes on the economy is influenced by the structure of marginal tax rates. The methodology suggested by their study is to determine the accurate marginal tax rate for the federal individual income tax system, characterized by a progressive rate structure and encompassing a diverse set of allowable and disallowed deductions from gross income.

Barro & Sahasakul (1983) justify the explicit use of the marginal rate in the tax schedule. They calculated the marginal tax rates from 1916 to 1980 using approximately weighted labour tax averages for aggregation. These rates, based on adjusted gross labour earnings, varied substantially over this long period. In addition to addressing the dynamics of average tax rates and deductions from taxable income, the analysis also encompasses the distribution of marginal tax rates. A notable finding was a fourfold rise between 1964 and 1980 in the proportion of households with adjusted gross incomes subjected to marginal tax rates of 35% or more.

Though the OECD values reported at the start of Section 4 provide the latest available estimates for the UK tax wedge, it is important to at least consider recent changes in the tax regime. For the UK, the Office of National Statistics (ONS, 2023) report highlights the impact of taxes on household income through both direct and indirect channels. Indirect tax, including VAT, is mainly determined by household expenditure, while direct tax indicates the proportion paid directly to the organization that imposed it. For the financial year 2021 to 2022, indirect taxation increased by 9.1%, while direct taxation increased by 4.8%. These percentages are as a proportion of household income and therefore independent of price inflation, though might be influenced by 'fiscal drag'. The main factors contributing to the increase of indirect taxation are VAT and hydrocarbon oil duties. The richest fifth of households paid 1.9 times more in indirect taxes than the poorest fifth, but a smaller proportion of their disposable income was spent on indirect taxes. These are important distributional impacts of changes in tax wedges in the UK.