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Funding the Future: The Impact of Population Ageing on Revenues across Levels of Government

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Abstract

Funding the future: the impact of population ageing on revenues across levels of government

Government revenues may be affected by economic growth and changes in demographics over time. The effect of economic growth can be captured by long-run buoyancy – responsiveness of government revenues to GDP growth – while the demographic effect can be captured by changes in labour income, asset income and consumption patterns over the life cycle, as well as population growth. This paper attempts to quantify the effect of population ageing on OECD tax revenues across different levels of government, by estimating error correction models of revenue buoyancies over the 1990 to 2018 period, by type of revenue, country and level of government. Multiple scenarios are used for the projections to 2040, which are combined with scenarios for the evolution of revenue bases using newly harmonized EU and UN National Transfer Accounts data as well as OECD Population Projections.

Keywords: Fiscal federalism, intergovernmental relations, demographics, tax policy, revenue buoyancy

JEL classification: H20, H71, J11

Résumé

Financement de l’avenir : l’impact du vieillissement de la population sur les recettes à différents niveaux d'administration

Les recettes publiques peuvent être affectées par la croissance économique et les évolutions démographiques dans la durée. L’effet de la croissance économique peut être appréhendé au moyen de l’élasticité à long terme (la réactivité des recettes publiques à l'augmentation du PIB), tandis que l’effet de la démographie peut être appréhendé par l'évolution des revenus du travail, des revenus du capital et des schémas de consommation sur le cycle de vie, ainsi que par la croissance de la population. Ce document s’emploie à quantifier l’effet du vieillissement de la population sur les recettes fiscales dans la zone OCDE à différents niveaux d'administration, en estimant des modèles à correction d’erreur des élasticités des recettes entre 1990 et 2018, par type de recette, pays et niveau de gouvernement. De multiples scénarios sont utilisés pour effectuer des projections jusqu’en 2040, en les associant à des scénarios d'évolution des bases de recettes établis à partir des données provenant des Comptes de transferts nationaux de l’UE et des Nations Unies récemment harmonisés, ainsi que des projections démographiques de l’OCDE.

Mots-clés : fédéralisme budgétaire, relations entre les différentes administrations, démographie, politique fiscale, élasticité des recettes

Classification JEL : H20, H71, J11

Funding the Future: The Impact of Population Ageing on Revenues across Levels of Government

By Sean Dougherty, Pietrangelo de Biase, and Luca Lorenzoni[1]

1. Introduction

1. In many OECD countries, the financing of the health systems will be put under severe pressure over the next decades. Population ageing is likely to increase the demand for health services and to reduce the labour force. Both factors are expected to negatively impact the sustainability of health systems – the former through an increase in government expenditures and the latter through a decrease in government tax revenues that are affected by changes in the labour market. This is especially worrisome considering that a large proportion of the overall funding of health and old age care services depends on revenues generated out of taxes and/or mandatory social contributions.

2. This fiscal pressure on government budgets is expected to be asymmetric, both across and within countries. Such cross-country differences are expected because countries differ with regard to the pace at which their populations are ageing, as well as funding streams and assignments of expenditures and revenues across levels of government. With respect to revenues, not only do different government revenue sources have different long-term buoyancies (*i.e.,* sensitivity to economic growth) but also some sources may be more heavily affected by demographic and labour force changes than others.

3. This study is part of a larger project aimed at assessing long-term fiscal challenges for OECD countries due to population ageing. This paper focuses exclusively on government revenues, while another study examines government expenditures on health (see de Biase et al., 2022). The main goal of this study is to quantify the magnitude of population ageing on tax revenues from different levels of government. Considering multiple levels of government is particularly important for policy recommendation purposes given that in a majority of OECD countries, healthcare and old-age care spending are shared between central, local and, if applicable, state governments. Hence, fiscal imbalances caused by population ageing can differ across levels of government and may require reforms either led by a specific level of government or related to intergovernmental fiscal relations. This paper complements other pieces that focus on the impact of population ageing across levels of government (see, for instance, Colin & Brys, 2020) quantifying the impact of population ageing on revenues.

[1] This document was prepared for the 2021 Annual Meeting of the OECD Network on Fiscal Relations across Levels of Government, as a companion paper to "Ageing and the long-run fiscal sustainability of health care across levels of government", issued as Fiscal Federalism Working Paper No. 38. It was prepared by Pietrangelo de Biase, consultant to the Fiscal Network, under the supervision of Sean Dougherty, head of the Network Secretariat and Luca Lorenzoni, OECD Health Division. Helpful feedback was received in discussions with delegates and experts. We are especially grateful for detailed comments from David Bradbury, Bert Brys, Céline Colin, Michelle Harding, Sean Kennedy, Emmanuelle Modica, Alexander Pick & Yannick Rehm of the OECD Centre for Tax Policy & Administration as well as Yvan Guillemette, Sébastien Turban, Catherine Macleod & Douglas Sutherland of the OECD Economics Department.

Box 1. Summary of main findings

- Government revenues are projected considering the effects from economic growth and demographic changes. The effect of economic growth on government revenues is captured by long-run buoyancy – responsiveness of government revenues to GDP growth – while the effect of changes in the structure of the population on government revenues is captured by changes in the tax base given age profiles for labour income, asset income and consumption over the life cycle.
- Considering only long-run buoyancy effects, for all taxes except the corporate income tax (CIT), the median increase in tax revenues is in line with the increase in GDP growth – for the general government[2] this expected increase varies from 96% (payroll taxes) to 101% (property taxes) of the growth in GDP, while revenues from the CIT are expected to grow 11% more than GDP growth.
- Countries can be separated into three groups with respect to long-term government revenue growth: 1) countries in which demography might increase government revenues because of both an increase in the population and changes in the structure of the population (only four OECD countries), 2) countries in which changes in the structure of population growth will decrease revenues, but population growth will offset this effect (the largest group, with half of all OECD countries), and 3) countries in which both population will decrease and changes in the structure of the population will lead to a reduction in government revenues (the remaining countries).
- Almost half of OECD countries are expected to see a positive impact from demographic changes on labour income but, in per capita terms, this proportion shrinks to only 4 out of 38 countries.[3] That is because the effects of population growth are substantially larger than the effects from changes in the structure of their populations, at least over the forecasted period.
- Countries that are expecting their populations to grow also tend to be less impacted from changes in the structure of their populations as, in these countries, a proportion of this growth is going to occur in age groups that are part of the labour force and, therefore, this increases tax revenues from PIT (personal income taxes), payroll taxes and social security contributions (SSCs).
- Revenues from PIT, SSCs and payroll taxes are expected to decrease in per capita terms due to the impact of population ageing on labour income (9% decrease on average). Revenues from asset income are expected to increase in per capita terms, as older people tend to have more asset income than younger people (7% increase on average).[4] Private consumption – the tax base for taxes on goods and service – does not vary substantially after the beginning of adulthood and, thus, GST/VAT revenues are expected to remain roughly constant in per capita terms with population ageing.
- Since governments rely more on PIT, SSCs and payroll taxes than on asset income, population ageing is expected to lead to a fall of up to 8% of general government revenues in per capita terms (in all but four OECD countries revenues are expected to fall).

[2] General government consists of central, state and local governments and the social security funds controlled by these units.

[3] These countries are Colombia, Costa Rica, Mexico and Türkiye.

[4] Asset income is the proxy used to estimate corporate income taxes in the design of the National Transfer Accounts (United Nations, 2013).

- As a share of GDP, the average decrease in the government revenue-to-GDP ratio is 4% for central and general governments, and 1% for subnational governments (SNGs), as the latter rely relatively more on property taxation and less on taxes on labour income. At the central/general government level, the decrease can be explained by two facts: 1) the mean buoyancy is below one for the general and central levels of government (0.99 and 0.97, respectively) and 2) the effects from changes in the age structure are by-and-large negative.

4. This paper covers a wide range of countries with the purpose of drawing general conclusions on the overall impact of population ageing on government revenues up to 2040 and their main drivers. This type of study requires simplifying assumptions that can be made to all countries involved. Thus, it contrasts with single-country case studies, which use country-specific micro and policy data to model government revenues with more precision. No specific reactions of policy makers to population ageing are modelled in the scenarios analysed in this paper. Although this is not a realistic assumption, such an analysis is useful for giving a general sense of the potential impact of population ageing and providing for a high level cross-country comparison, which may motivate more detailed country-specific analysis to inform future reform options (for an analysis that covers the reactions of policymakers to population ageing, see Guillemette & Turner, 2021).

5. Our discussion and analysis proceed as follows. In Section 2 we delve into the revenue structure across countries and levels of government. In Section 3 we explain the methodology used to forecast government revenues without considering population ageing effects and show the main results. In Section 4, we explain the methodology used to estimate the impact of population ageing on government revenues and explore its results. In Section 5 we show the results of the combination of the buoyancy and population ageing effects. We conclude by laying out potential policy implications and recommendations with the purpose of alleviating the impact of population ageing on government revenue.

2. Revenue structure across countries and levels of government

6. There are substantial differences in the revenue structure across countries and across levels of government. Countries and levels of government rely on different sources of revenues and population ageing affects these revenue sources differently. This section explores revenue figures across OECD and partner countries and across levels of government, so heterogeneous effects from population ageing can be better captured and understood. Tax revenue data come from OECD Revenue Statistics.[5]

2.1. A review on government's revenue structure

7. Government revenues can be distinguished between tax and non-tax revenues. According to the OECD Interpretative Guide, taxes are compulsory, unrequited payments to the general government. Taxes are calculated through the multiplication of a tax rate to a tax base (*e.g.*, income, property, consumption, payroll, carbon emission, etc.). Non-tax revenues, on the other hand, are defined by exclusion: revenues that are not tax revenues are classified under this heading. They include a multitude of revenue sources that range from the profits of state-owned enterprises to parking fees and fines, excluding funds raised through loans.

8. Tax systems vary across levels of government. In theory, the central government is expected to have a more diversified tax mix than lower levels of government. That is because not all taxes can be collected efficiently at the subnational level. First, SNGs tend to employ more efficiently their administration when collecting fewer taxes with larger revenue capacity than when collecting a large number of different

[5] The harmonised tax data in OECD Revenue Statistics allows cross-country comparisons on a like for like basis.

taxes with smaller revenue capacity[6] (Mikesell, 2012). Second, mobile tax bases are more prone to tax competition across jurisdictions, which can lead to distortionary effects. For instance, jurisdictions can lower their tax rates and provide tax benefits to encourage taxpayers to move to their jurisdiction, which increases this jurisdiction's tax revenues but reduces tax revenues in aggregate (Blöchliger & Pinero, 2011). Therefore, large and immobile tax bases are more commonly ascribed to lower levels of governments.

9. Governments also have sources of revenue that are unrelated to taxes, which are generally classified by exclusion as non-tax revenues (*i.e.,* all sources of revenues that do not come from taxes fall under this category). Non-tax revenues encompass a large heterogeneity of revenue sources, such as intergovernmental grants, interest receipts, property rents, dividends and profits from state-owned enterprises, and charges and fees from services provided by governments to specific groups (*e.g.,* toll roads, medical service charges, entrance fees, among others). Different from tax revenues, most non-tax revenues tend to involve fixed amounts or charges not directly linked economic activity and, thus, are generally not significantly related to the economic cycle (Price et al., 2015).[7] They also tend to be very country specific and, therefore, it is challenging to compare countries with regard to their non-tax revenues in an empirical manner (for such analysis see Mourre & Reut, 2017).

10. The reliance on non-tax revenues not only varies across countries but also across levels of governments. Lower levels of government tend to rely more on tariffs and fees than the central government as they commonly derive from the provision of local public services such as parking fees and fines, museum fees, among others. Second, in no OECD countries are SNGs' own tax revenues sufficient to fund all of their expenditures[8] and, thus, central governments fill this gap with intergovernmental transfers, which often represent a substantial source of SNGs' revenues over which SNGs have no or little discretion.

2.2. Cross-country analysis of government revenues

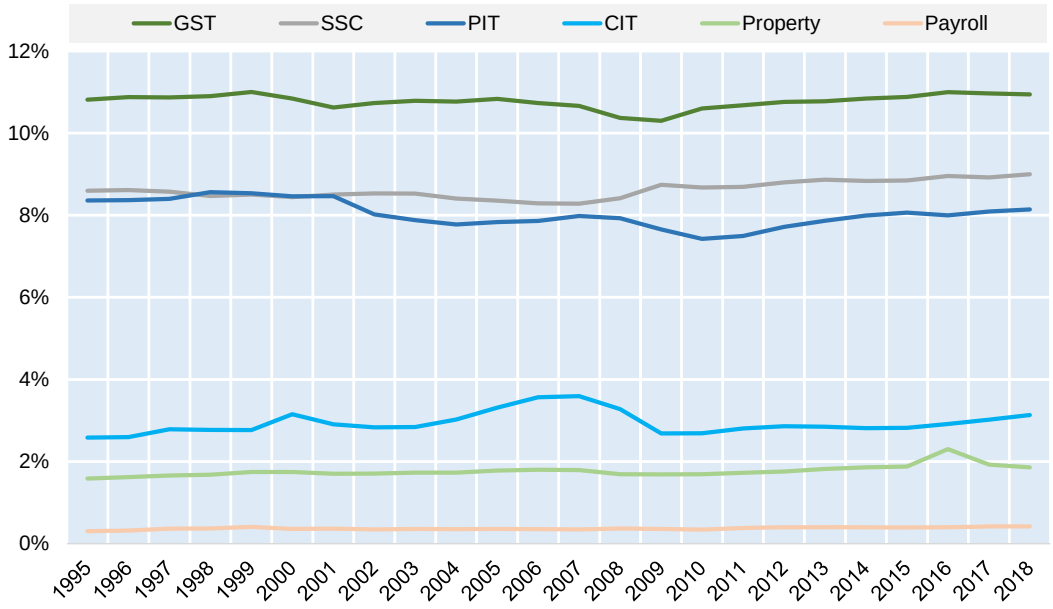
11. In terms of tax revenues, the most important taxes in OECD countries are (in order) GST/VAT, SSCs, PIT, CIT, property taxes and payroll taxes (Figure 1). This rank-order is roughly the same as it was in 1995 and variations over time have been modest. More specifically, from 1995 until the COVID-19 crisis, the OECD average for no single tax type experienced an increase or decrease of more than 1 percentage point as a share of GDP and the highest variation was for CIT, which experienced an increase of 0.6 percentage points as a share of GDP (for a detailed analysis of tax revenue trends see OECD, 2020).

[6] In other words, central governments tend to benefit from economies of scale.

[7] For instance, a policy that boosts public dividends in detriment of profit reinvesting may generate a large source of revenue that dwarfs the effect of the economic activity. One-off movements in receipts could arise from government measures such as a public company privatisation or government auctions. Nevertheless, there are exceptions, such as rents and royalties, which can be highly procyclical.

[8] This aspect of fiscal federalism is known as the vertical fiscal gap.

Figure 1. General governments' tax revenues as a percentage of GDP over time (OECD average)



Source: Authors' elaboration based on OECD Revenue Statistics (most recent edition).
Note: General government consists of central, state and local governments and the social security funds controlled by these units. PIT, CIT, SSCs and GST/VAT refer to personal income tax, corporate income tax, social security contributions, and good and service tax.

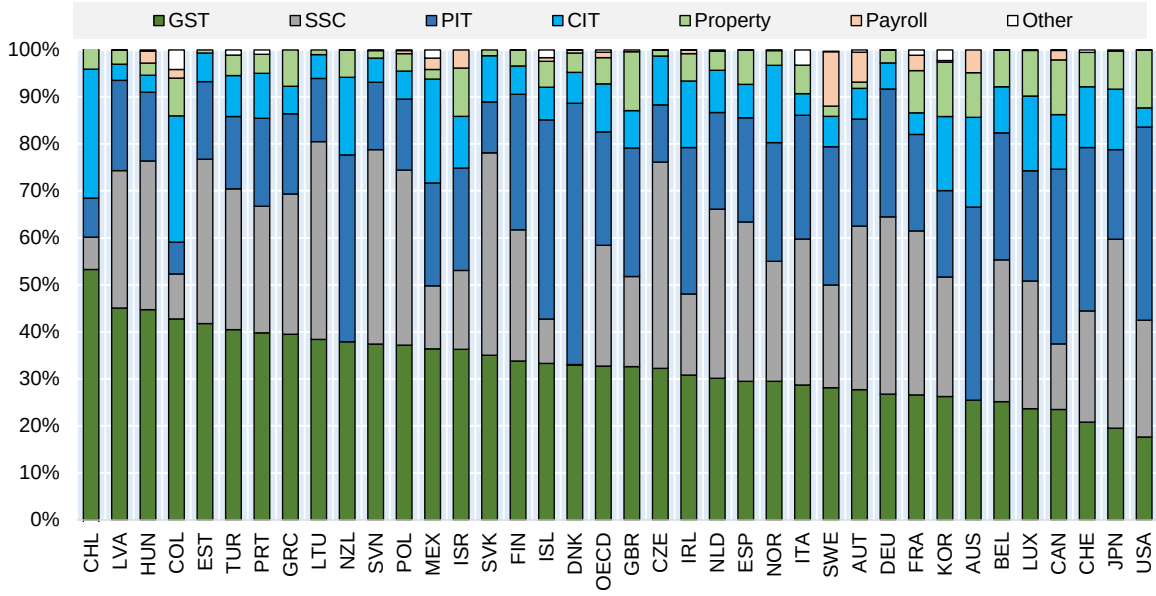
12. Country-specific variations in tax revenues as a percentage of GDP over the last two decades are also modest, with only 10 out of 37 countries[9] experiencing an increase of more than 2.5 percentage points of GDP for any tax type. The highest country-specific variation is observed in Iceland's PIT revenues, which increased 6.2 percentage points as a share of GDP in this period (see Annex A for country and tax specific variations). It is safe to say, therefore, that, by and large, countries' tax mixes have remained relatively stable over in recent decades.

13. Although the tax composition tends to vary little over time, there is substantial cross-country variation. Figure 2 shows the tax revenue composition of the general government in OECD countries. Some countries rely substantially on PIT (e.g., more than 40% of all tax revenues in Denmark, Iceland, the United States and Australia), while in other countries PIT revenues are only a minor source of funding (e.g., in Chile and Colombia they represent 6.8% and 8.3% of all tax revenues, respectively). The same can be said about CIT and SSC revenues as a percentage of total taxes.

14. GST/VAT's revenues, on the other hand, represent at minimum 17.6% of total tax revenues (the United States) and can represent even more than half of all tax revenues (e.g., 53.3% in Chile). Revenues from taxes on payroll rarely represent a substantial share of total taxes – they represent more than 5% of total taxes in only 2 out of 37 countries (e.g., 11.6% for Sweden and 6.4% for Austria) and they represent less than 1% of total taxes in 28 countries. Property tax revenues tend to be less important as a share of total taxes, ranging from 0.7% (e.g., Estonia) to 12.5% (e.g., the United Kingdom), with 20 of the 37 OECD countries in the 5.0% to 12.5% range while they fall between 0.7% and 5.0% in the other 17 countries.

[9] Costa Rica not included in the analysis (for details, see Annex A).

Figure 2. General government tax revenue composition in OECD countries (% of tax revenues)



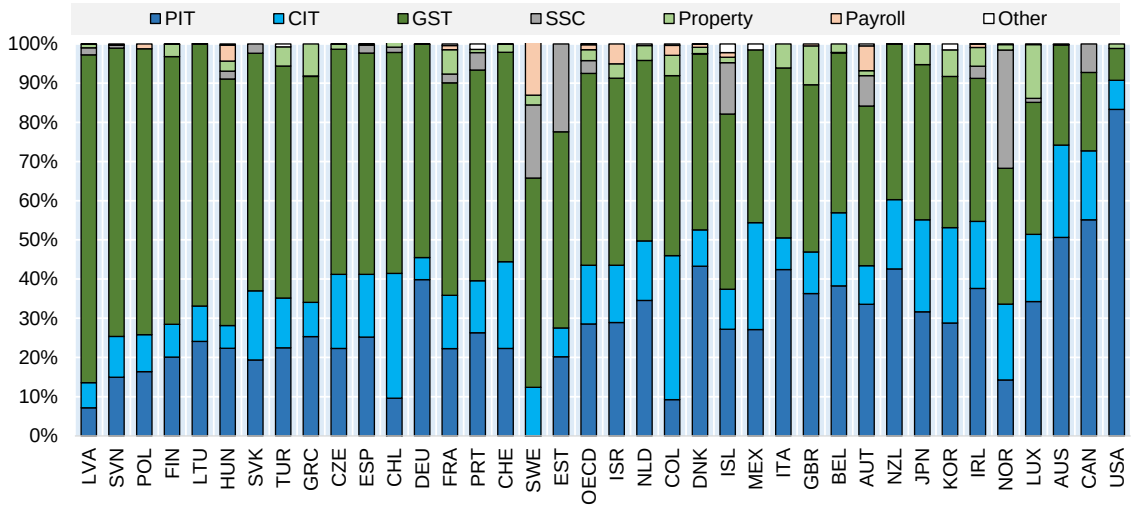
Note: General government consists of central, state and local governments and the social security funds controlled by these units. PIT, CIT, SSCs and GST/VAT refer to personal income tax, corporate income tax, social security contributions, and good and service tax. Income taxes not allocable between PIT and CIT are, for the purpose of study, allocated to PIT and CIT proportionally to their shares as a percentage of income taxes. Values of 2018.
Source: Authors' elaboration based on OECD Revenue Statistics.

2.3. Comparing central and subnational government revenue portfolios

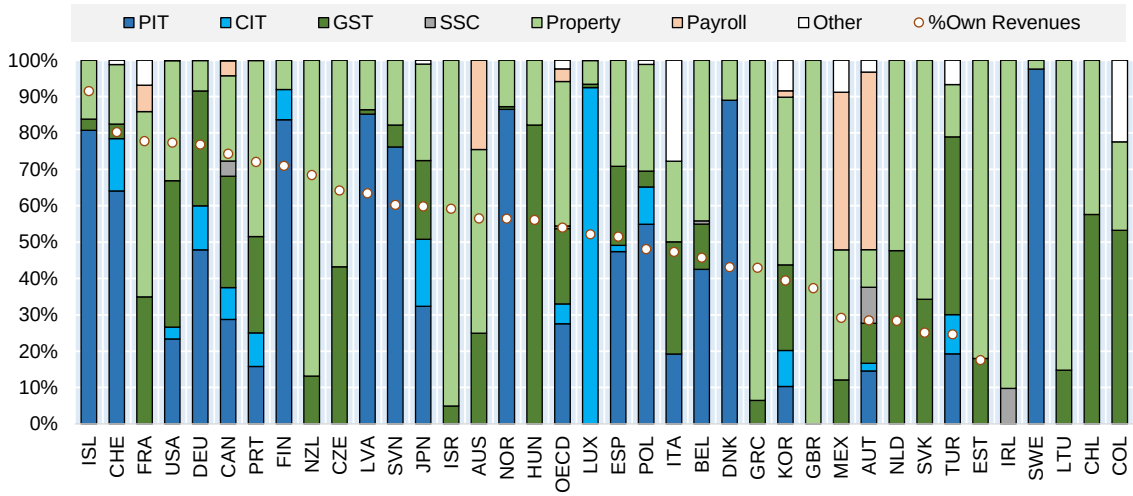
15. Figure 3 shows the composition of tax revenues of different levels of government in OECD countries. An analysis of the chart confirms the theoretical expectations that SNGs tend to rely more on immobile tax bases than central governments, especially due to their reliance on property taxation. In contrast, central governments tend to rely more on GST/VAT and CIT than SNGs. It is also worth noting that in many countries tax revenues represent only a small portion of SNGs' total revenues – in 13 out of 33 OECD countries SNGs own tax revenues represent less than half of their total revenues. Social security funds (SSF) revenues stem largely from social security contributions, with the only notable exception in the OECD being France, in which income taxes represent roughly 25% of all SSF revenues.

Figure 3. Tax revenue composition across levels of government in OECD countries (% of tax revenues)

a. Central governments



b. Subnational governments

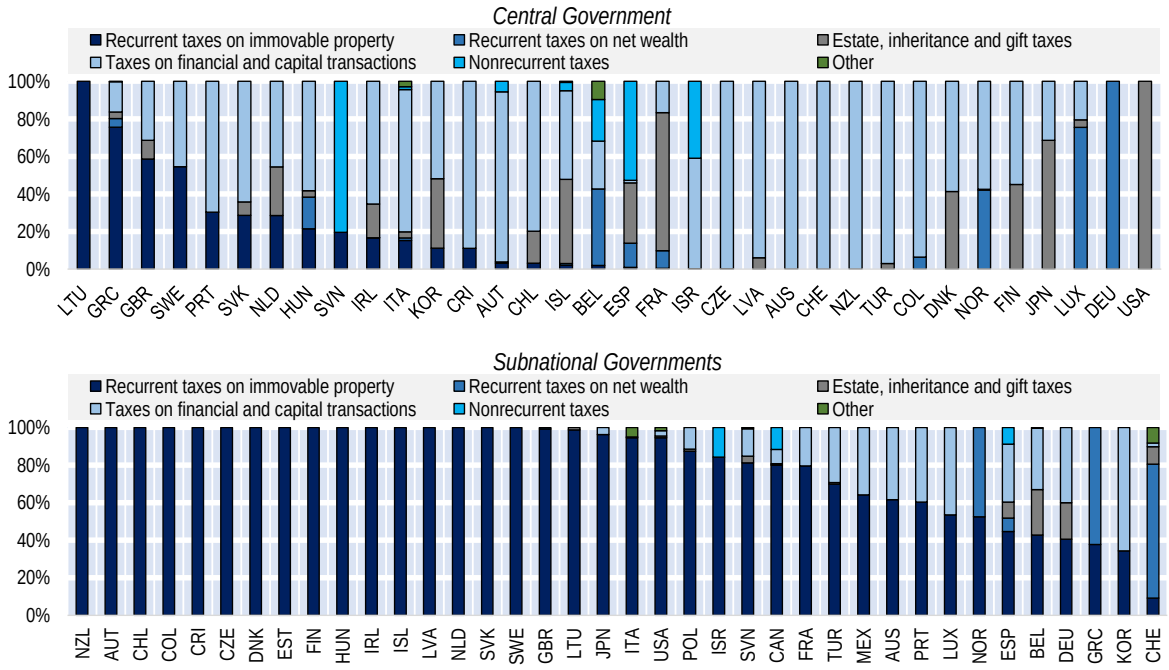


Note: PIT, CIT, SSCs and GST/VAT refer to personal income tax, corporate income tax, social security contributions, and good and service tax. Own Revenues in panel B refer to the percentage of SNGs revenues that do not come from intergovernmental grants from upper levels of government – when zero the data are missing. Revenues from social security funds were not attributed to any level of government. Income taxes not allocable between PIT and CIT were, for the purpose of this graph, allocated to PIT and CIT proportionally to their shares as a percentage of income taxes. Values of 2018. Data on own revenues is missing for Ireland, Sweden, Lithuania, Chile and Colombia.
Source: Authors' elaboration based on OECD Revenue Statistics and Fiscal Decentralisation database.

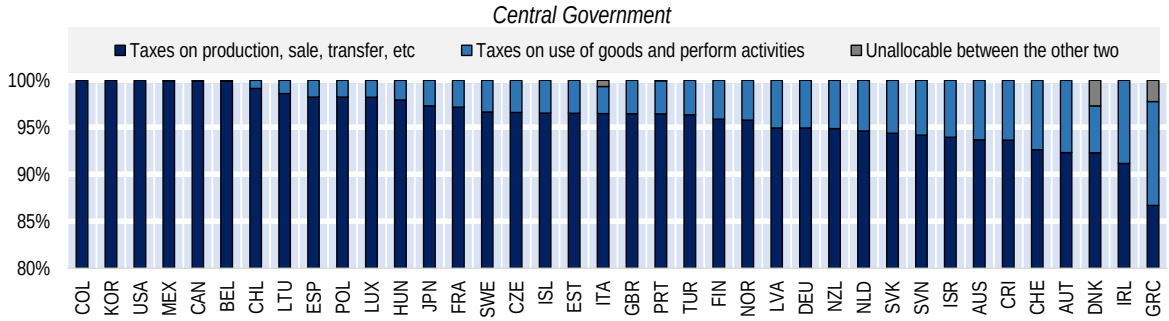
16. Central governments and SNGs also differ significantly in the composition of their revenues from property taxes and taxes on good and services. Figure 4, on the left-hand side, shows that central governments' property tax revenues come mostly from taxes on financial and capital transactions and from estate, inheritance and gift taxes, while those from SNGs come mostly from recurrent taxes on immovable property. Figure 4, on the right-hand side, on the other hand, reveals that GST/VAT revenues from central governments usually come from levies on production sale or transfers, while those from SNGs can come from levies either on production, sale or transfers, or on the taxes on use of goods or on permission to use goods or perform activities.

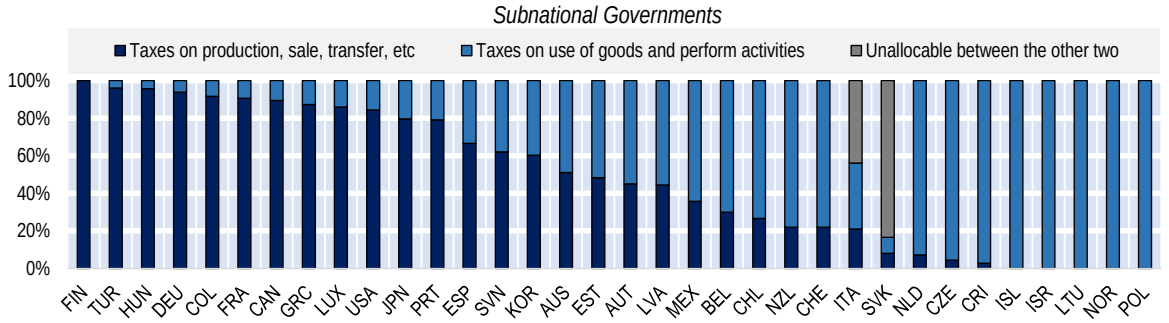
Figure 4. Composition of property and good and service tax revenues across levels of government (% of the revenues from the respective tax)

a. Property taxes



b. GST/VAT





Source: Authors' elaboration based on OECD Revenue Statistics.

2.4. Non-tax revenues

17. Non-tax revenues are estimated by taking the difference between government revenues from the OECD System of National Accounts (SNA) and tax revenues from the *OECD Revenue Statistics*.[10] While there are some differences between the OECD classification of taxes and the SNA definition,[11] these differences mainly affect the identification of tax and non-tax revenues without altering the overall amount of revenues. It is important to note that according to the System of National Accounts manual, revenue values in the SNA are unconsolidated across the central and subnational levels of government (values of the *OECD Revenue Statistics* are, on the other hand, consolidated).[12] One consequence of using unconsolidated revenue values from the SNA to estimate non-tax revenues is that revenues collected at the central level and transferred to SNGs through intergovernmental grants are recorded twice (*i.e.,* as revenues flowing to central government and as non-tax revenues in SNGs). The median value of grants transferred from higher levels of government to SNGs represents 20% of central government and social security funds' revenues and 80% of SNG non-tax revenues in 2019. The intergovernmental grants are an important source of revenues for SNGs and are a significant expenditure for central governments, ranging from 9% of total revenues in Iceland to 92% in Mexico, and amounting to 50% on average for OECD countries in the same year.

18. Similar to tax revenues, reliance on non-tax revenues also varies across countries and across levels of government. General governments' non-tax revenues range from 9.6% (Italy) to 30.6% (Norway), with most OECD countries in the range of 10% to 20% (Figure 5). For central governments, non-tax revenues can be as little as 2% (Czech Republic) or can be as high as 37% (Iceland), while for the majority of them non-tax revenues represent from 10% to 30% of their total revenues.

19. Regarding differences across levels of government, SNG revenues tend to rely on a wide range of revenue streams, consisting of own tax revenues, tax sharing, intergovernmental grants, and other sources of non-tax revenues such as tariffs and fees. Therefore, non-tax revenues tend to be particularly prominent at the subnational level, ranging from 21.8% (Iceland) to a 97.2% (Estonia), with this value ranging from 40% to 70% for SNGs in most OECD countries. A major caveat when analysing this data is that intergovernmental grants are not considered tax revenues by the System of National Accounts and a

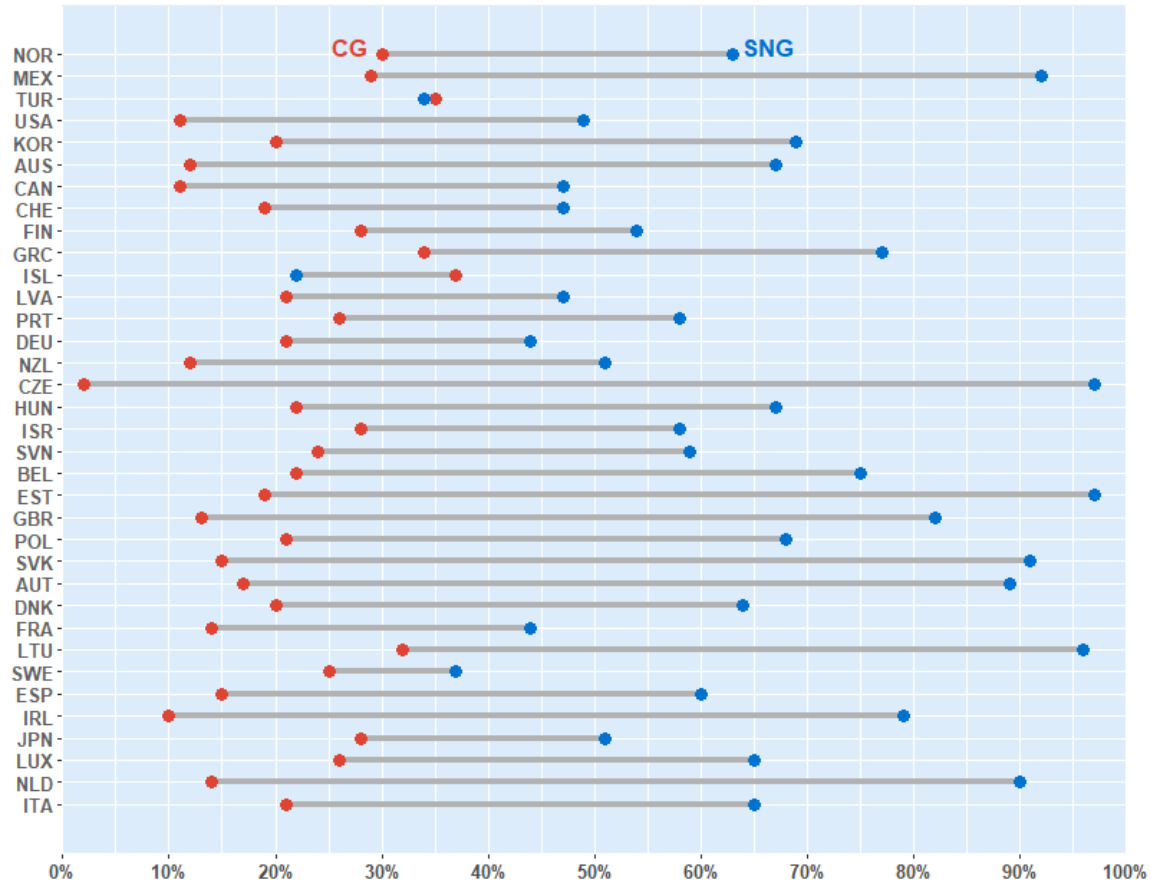
[10] More precisely, data on total tax revenue were obtained from *OECD Revenue Statistics*. Comparative tables for OECD countries while the total government revenues data were obtained from the OECD System of National Accounts (code GTR of Table 12). Total government revenues from the general government were subtracted from total tax revenues from the supranational level of the *OECD Revenue Statistics* to estimate non-tax revenues. The same subtraction was made for other levels of government.

[11] The main difference is that *OECD Revenue Statistics* includes compulsory social security contributions paid to general government in total tax revenues whereas the SNA does not. Other differences are documented in §90 of *OECD Revenue Statistics* (for more details see https://www.oecd.org/tax/tax-policy/oecd-classification-taxes-interpretative-guide.pdf).

[12] Consolidation presents statistics for a set of units/entities as if they constituted a single unit by removing all flows and merging stock positions among the units/entities being combined. Consolidation of revenue accounts can be done by subtracting the flows between units from the revenues of either: 1) the collector of the income or 2) the receiver of the income. The first method attributes the revenues to the unit that is responsible for spending them (*e.g.,* GST/VAT that is collected by the central government and transferred to SNGs will be classified as SNG revenues), while the second method attributes the revenues to the unit that is responsible for collecting them (*e.g.*, GST/VAT that is collected by the central government and transferred to SNGs will be classified as central government revenues). Both consolidation methods are useful and should be chosen based on the purpose of the analysis at hand. For further discussion on data consolidation in the context of the fiscal impact of population ageing across levels of government, see de Biase et al. (2022), notably its Annex D.

substantial portion of these grants are tied to tax revenue streams in the form of tax sharing[13] or mandatory general-purpose grants,[14] which represent, in essence, a type of "tax revenue". Although SNGs might have limited autonomy to change the tax policy related to these revenues, they behave cyclically as tax revenues, as they represent an entitlement of tax revenues collected by upper levels of government. Therefore, this statistic can be misleading if not put into context. Box 2 explores the role of grants on health funding at the subnational level.

Figure 5. Non-tax revenues as a share of total revenues in OECD countries (% of total revenues)



Note: Tax revenue data comes from the OECD Revenue Statistics while non-tax revenues are estimated by taking the difference between government revenues from the OECD System of National Accounts (SNA) and tax revenues from the OECD Revenue Statistics (for 2018).
Source: Authors' elaboration based OECD Revenue Statistics and OECD System of National Accounts.

[13] Tax sharing is a fiscal arrangement in which SNGs are endowed with a portion of the revenue that is collected at a different level of government to complement its own revenue sources (for more on this topic see Blöchliger & Petzold, 2009).

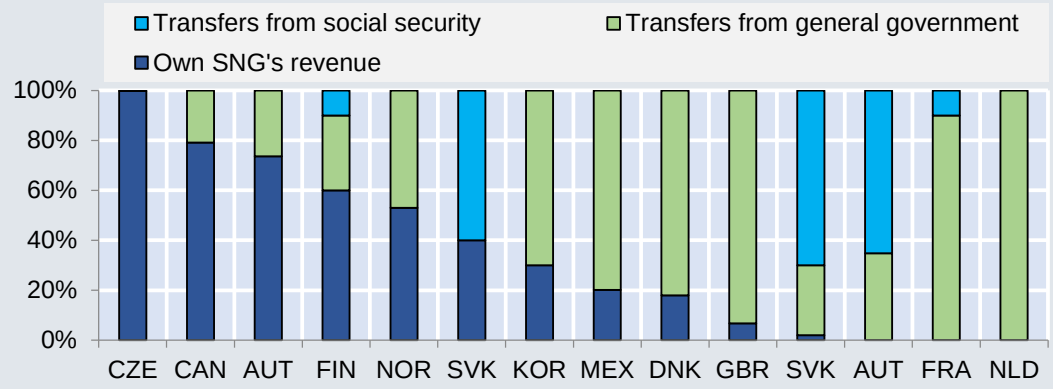
[14] Mandatory general-purpose grants are funds that upper levels of government must transfer to SNGs (*e.g.,* commonly by the force of the law or constitution) and over which the grantee's use of the grant is not controlled (for more on this topic see Bergvall et al., 2006).

Box 2. Funding of subnational health services

Health care is particularly affected by population ageing as older adults tend to consume more health care services than the working population. Health care expenditure (see de Biase & Dougherty, 2021) and decision-making (see Dougherty & Phillips, 2019) are allocated across levels of government, with SNGs often being responsible for a substantial portion of health care expenditure and/or policy decisions.

Due to the relevance of SNGs in health care provision, the OECD has surveyed countries to understand how SNGs fund their health expenditures.[15] This survey showed that 44% of the funding of health care expenditure at the subnational level comes from SNGs' own revenues, 42% from central government transfers and 14% from transfers from social security funds. These values, though, vary substantially across countries. SNGs from the Netherlands, for instance, rely exclusively on grants from the central government while SNGs from the Czech Republic rely exclusively on their own revenues (see Figure 6).

Figure 6. Sources of revenues financing SNG health expenditure (% of health financing)

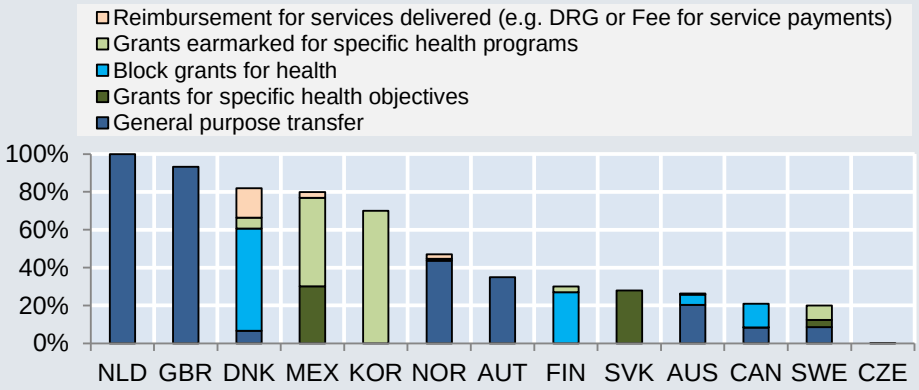


Source: OECD Survey of Budget Officials on Budgeting Practices for Health, 2013, as cited by Hulbert & Vammalle (2015)

Figure 7 depicts the characteristics of these transfers. Most of these grants are general-purpose (*i.e.,* can be spent freely and with no specific purpose) but some countries resort to block grants (*i.e.,* given by the grantor for a specific purpose but with no condition on how the funds should be spent) or earmarked grants (*i.e.,* can only be spent on certain items).

[15] OECD Survey of Budget Officials on Budgeting Practices for Health, 2013.

Figure 7. Composition of transfers from central authorities as a share of total SNG health care spending



Source: OECD Survey of Budget Officials on Budgeting Practices for Health, 2013, as cited by Hulbert & Vammalle (2015)

Lastly, the ability of central government authorities to modify the value of grants over time tends to be limited in countries in which SNGs are responsible for a substantial portion of health expenditure, but are considerable in countries in which SNGs have a minor role in health care provision. More precisely, 11%, 34% and 33% of the surveyed countries reported that central governments can vary total resources transferred to SNGs for health care purposes to a large, moderate, and small extent, respectively. In the remaining 22% of the cases the resources vary on a multi-year basis.

Source: Hulbert & Vammalle (2015).

3. Revenue buoyancy

3.1. Methods

20. Buoyancy and elasticities are estimates that capture the sensitivity of government revenues to economic activity or the economic cycle. For instance, a buoyancy of 1.1 implies that a GDP growth of 1% will lead to an increase in revenues of 1.1%. They can be used to forecast government revenues based on forecasts of proxies for economic activity, such as GDP or the output gap, by multiplying the buoyancy/elasticity coefficient by the expected growth of the proxy at hand. In that manner, the reaction of revenues to economic activity is captured and reproduced in the future. Therefore, when using this forecasting method, it is implicitly assumed that the relationship between revenues and GDP of the past is going to be kept in the future.

21. The difference between these two coefficients is that tax elasticity controls for tax changes by excluding from the tax revenue series the estimated effects of changes in tax policy. In other words, tax elasticity measures the response of tax revenues to growth based on the current tax system while tax buoyancy measures the response of tax revenues to growth based on historical data, which includes both the tax elasticity and the changes in the tax system. As a result, forecasts using tax elasticity assume that there will be no change in tax policy throughout the forecasting period while tax buoyancy assumes that the same changes made in the past are going to happen in the forecasting period. In both cases, though, the forecast disregards future policy changes that policymakers are going to implement to deal with pressures from population ageing.

22. Studies often estimate the elasticity or buoyancy of government revenues with respect to specific tax bases (Princen et al. 2013), the output gap (Price et al. 2015), or GDP (Anderson & Shimul, 2018; Belinga et al., 2014; Deli et al., 2018; Dudine & Jalles, 2017; Köster & Priesmeier, 2017; Lagravinese et al., 2020). Methods using GDP are more common for multiple reasons. First, GDP is broadly available while the output gap depends on the estimation of and assumptions on potential GDP, while effective tax bases are a function of tax policy. Second, a literature review on the topic from Köster & Priesmeier (2017) concluded that estimates based on output gaps and GDP are rather similar and, thus, the use of GDP, which is simpler to gather data on and to explain, should be preferred. Third and lastly, as most studies estimate elasticity/buoyancy with respect to GDP, cross-study comparisons are enhanced. For these same reasons, this paper will use the elasticity/buoyancy with respect to GDP.

23. Due to the fact that tax elasticity estimates the effect of economic activity on tax revenues in isolation, it is the preferred method for some authors, such as Jenkins et al. (2000). In contrast, other authors, such as Lagravinese et al. (2020), Deli et al. (2018), Dudine & Jalles (2017) and Belinga et al. (2014), preferred tax buoyancy in their studies for multiple reasons. First, policymakers do change tax policy over time and even endogenously (*e.g.,* they may raise tax rates in times of crisis to raise more revenues *and vice versa*[16]), which should be captured by the forecast. Second, the counterfactual revenue time series (*e.g.,* the time series with the exclusion of the effects from exogenous tax policy changes) can only be estimated and, thus, can be biased and hinder cross-country comparisons as a result of non-harmonised assumptions of "exogenous" tax policy changes.

24. As the purpose of this study is to forecast the revenues of different levels of government from OECD countries through to 2040 considering the effects of population ageing, we choose to use tax buoyancy. This is also because in order to estimate tax elasticity coefficients, it would be necessary to disentangle the effects from exogenous tax policy in the revenues' time series of all jurisdictions of all levels of government of all OECD countries (that is because each jurisdiction has its own tax policy). There is no structured and harmonised dataset with the necessary information to exclude these effects and, therefore, an estimation of tax elasticity would be prone to biases related to data harmonisation and completeness in the generation of the counterfactual time series.

3.2. Estimating long-run revenue buoyancy coefficients – ECM

25. This study uses an error correction model (ECM) with the purpose of capturing the dynamic relationship between revenues from different levels of government and GDP.[17] An ECM assumes that there is a long-run and short-run relationship between tax revenues and GDP and that short-term deviations from the long-run relationship are continuously adjusting towards the long-run relationship at a certain speed. Hence, four coefficients are estimated: the short-run buoyancy, the long-run buoyancy, the speed of adjustment coefficients and the intercept. As in this study we are forecasting government revenues in 2040, long-run buoyancy is the coefficient of interest.[18]

[16] For instance, Lutz (2008) found evidence that SNGs in the United States often increase the statutory tax rates for immovable property taxation in order to offset revenue losses in downswings and decrease these rates in upswings of house prices to smooth tax hikes. Another common example of such endogeneity is through indexation, for instance through the income tax brackets for PIT and SSC.

[17] Other authors that employed ECMs to estimate tax elasticity or buoyancy are Lagravinese et al. (2020), Deli et al. (2018), Köster & Priesmeier (2017), Dudine & Jalles (2017), Mourre & Princen (2015), Belinga et al. (2014), Koester & Priesmeier (2012), Wolswijk (2009) and Bruce et al. (2006).

[18] Short-run buoyancy/elasticity coefficients are particularly useful to analyse the impact of the economic cycle on government revenues. An analysis of the short-term tax buoyancy across levels of government in OECD countries can be found in Dougherty & de Biase (2021).

26. More precisely, the following variation of an auto-regressive distributed lag (ARDL) model is estimated using ordinary least squares (1-stage approach)[19]:

$$\Delta ln(R_{c,l,i}) = \varphi_{c,l} + \alpha_{c,l} ln(R_{c,l,i-1}) + \beta_{c,l}\, ln\left(GDP_{c,i-1}\right) + \rho_{c,l} \Delta ln(GDP_{c,i}) + D_{c,i} + \epsilon_{c,l,i} \qquad (1)$$

27. Where *R*, *D*, *c*, *l* and *i* refer to government revenues, dummy for negative real GDP growth,[20] country, level of government and time, respectively. φ is an intercept, ρ is the short-run buoyancy, α is the speed of adjustment and $-\beta/\alpha$ is the long-run buoyancy (the coefficient of interest). Variables are in real terms (deflated by the GDP deflator).[21] It is worth mentioning that the long-run buoyancy coefficient aims at capturing the long-run relationship between GDP and revenues and, therefore, is the superior coefficient for sustainability analysis. In addition, these long-run buoyancy coefficients are symmetric across the cycle and, therefore, GDP movements are expected to impact government revenues identically in upswings and downswings.[22] On the other hand, short-run buoyancy coefficients capture the relationship between revenues and the cycle and, thus, are superior for analysing the impact of shocks on government revenues (for an analysis of short-run buoyancies using this same model, see Dougherty & de Biase, 2021). The advantage of using an ECM instead of a simple estimation of buoyancies by regressing GDP on government revenues is that these two different relationships (long and short-run) can be disentangled and, thus, estimated more precisely.

28. Furthermore, this model allows for heterogeneity of all estimated parameters, including their variances, as coefficients are estimated independently for every combination of country and level of government. This heterogeneity can be explained theoretically and empirically by at least three reasons. First, countries and levels of government differ substantially with regard to their tax mixes (see previous section) and each tax base is expected to have a different sensitivity to variations in the economic activity (*e.g.,* profits and asset income, which is the base for CIT, vary more widely with economic activity than property values, which is the tax base for recurrent taxes on immovable property). Second, there is evidence that many country-specific factors affect tax buoyancy such as trade openness, human capital, inflation and output volatility (Dudine & Jalles 2017). Third, tax and revenue policies affect the revenue buoyancy, as they both vary across countries and levels of government. Therefore, pooling data or using fixed effects approaches in this case would create biases.

3.3. Data

29. All tax data come from the OECD Revenue Statistics and total revenues data come from the OECD System of National Accounts. Each cross-sectional unit refers to a combination of one OECD country and the respective level of government. As countries might have a varied number of levels of government,[23] this study grouped all lower levels of governments into the "subnational level" to enhance comparability. As this paper's goal is to provide overall estimates of the impact of population ageing on government revenues, this aggregation can be justified as it enhances cross-country comparability. Nonetheless, an

[19] Other authors that employ variations of this 1-stage ECM approach are: Khadan (2020), Lagravinese et al. (2020), Dudine & Jalles (2017) and Belinga et al. (2014). For a better understanding of this model, see Enders (2014).

[20] Dummy coefficients were, mostly, zero or close to zero and speed of adjustment coefficients were mostly negative and statistically significant, in line with theoretical expectations.

[21] Real terms are used to make the buoyancy coefficients compatible with the OECD projections for the GDP, which also are in real terms.

[22] This is not a concern in a long-run analysis as GDP forecasts usually disregard cyclical effects and, thus, assume an almost constant GDP growth rate throughout the forecasting period. This is the case in Guillemette & Turner (2021), whose GDP forecasts were used in this paper as an input to forecast government revenues.

[23] The OECD Revenue Statistics capture at most four levels of government: central, social security funds, state/regional and local.

analysis considering all subnational levels of government in isolation would provide more detailed information on the impact of reform to intergovernmental fiscal relations, as there might be cases in which state and local governments are going to be impacted differently and, when using this aggregation, these effects are averaged (weighted by the size of their revenues).

30. Revenues from the social security system were grouped along with those of the central governments. Again, this is a simplification to enhance cross-countries comparability as there are varying arrangements in OECD countries with SSC revenues accruing to SNGs in only a very small number of cases.[24] With that said, it is worth noting that in this setup each country has two levels of government: the central level (*i.e.,* consisting of central government and social security) and the subnational level (*i.e.,* consisting of local and, if applicable, state/regional levels) while the general government level is the aggregation of all of them. Estimations are in real values (deflated by the GDP deflator provided by the OECD System of National Accounts).

31. In general, the period analysed spans from 1990 until 2018, but differs by country depending on data availability. In case a country has less than 15 observations on revenues for a combination of tax type and level of government, this combination was dropped from the dataset due to the lack of data availability to estimate buoyancies.[25]

3.4. Scenarios for buoyancy

32. As a robustness check, three scenarios for the buoyancy coefficients are used. First, the baseline scenario is based on the assumption that buoyancy coefficients remain constant throughout the forecasting period (until 2040). Second, a unitary buoyancy scenario – that is, revenue growth is equal to GDP growth. Third, an intermediate scenario in which buoyancy coefficients converge to one by 2060 (note that the forecasting period is through 2040). These three scenarios capture the uncertainty with regard to the future revenue buoyancy. [26]

33. The rationale behind these three scenarios is that keeping buoyancy coefficients constant over the course of two decades may be too extreme, as it assumes that countries will pursue the same policy path they followed throughout the period that was used to estimate the buoyancy coefficients (1990-2018). As this assumption is unlikely, the goal of the 1st scenario is just to provide an overall estimation of what would happen in case countries repeat the same policies. The 2nd scenario, of unity buoyancies reflects the theoretical expectation that in the long-run tax buoyancies must be one, otherwise the government will outgrow the entire economy or will cease to exist – the first option is a theoretical impossibility while the second is extremely unlikely. The 3rd scenario, of buoyancies converging to one assumes that there is some inertia in policy paths and, therefore, buoyancies will gradually converge to their theoretical expectation of one by 2060.

3.5. Buoyancy estimates

34. Before delving into buoyancy estimates, it is worth illustrating the overall relationship between GDP and government revenues. Figure 8 shows that general government revenues and GDP are, to some degree, correlated. It is also clear that in some years this correlation is rather strong, while in others it is

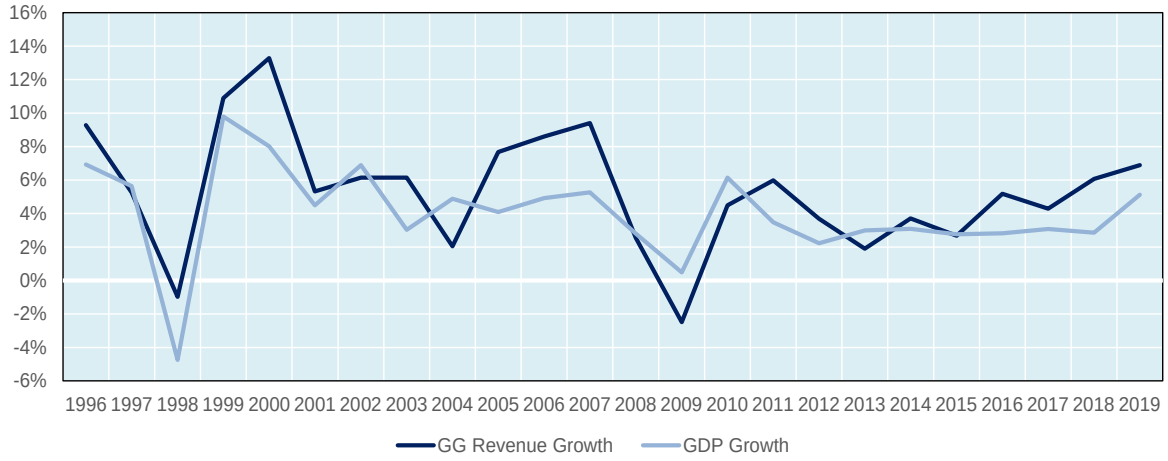
[24] In 2019 (prior to COVID-19 crisis), only in Austria, Belgium, Canada and Ireland SNGs were partially funded by SSCs. Of these countries, only in Austria did SSC revenues represent more than 10% of SNGs' tax revenues (*i.e.*, it represented 11.5%).

[25] Due to lack of data availability, four countries were dropped in the analysis of general government total revenues: Chile, Colombia, Japan and Türkiye.

[26] We selected 2060 as the convergence year so that this scenario would be compatible with GDP forecasts from Guillemette & Turner (2021).

weak. Overall, government revenues tend to overreact to GDP movements and there are rarely persistent differences between these two variables – that is, the growth in government revenues do not tend to be higher or lower than GDP growth for more than a couple of years. This suggests that their relationship is dynamic and that is why ECMs are often used to estimate buoyancies and elasticities.

Figure 8. General government's revenue growth compared to GDP growth, OECD average



Note: Revenue growth and GDP growth are shown in real terms. Average is unweighted.
Source: Authors' elaboration based on OECD System of National Accounts.

35. With that said, Figure 9 shows the distribution of the long-run buoyancy coefficients across levels of government and countries (application of Equation 1).[27] A comparison of the distributions across levels of government indicates that for PIT and CIT, the distribution of long-run buoyancy varies little across levels of government. This does not mean that in a specific country this difference cannot be large (for instance, in Germany, SNG CIT revenue buoyancy is 3.1, while the buoyancy of the central government is 1.4), but rather that there seems to be *no systematic differences* between the distributions of the buoyancies of different levels of government (*i.e.,* there is no tendency for CIT or PIT revenues from a certain level of government to be more buoyant than those of the others).This is not the case for property taxes and GST/VAT, however. Differences in the boxplots for these taxes in Figure 9 suggest that SNGs tend to have a slightly higher revenue buoyancy for both taxes.[28] These differences can potentially be explained by the fact that the taxes under the property tax and GST/VAT headings differ across levels of government and, as result of this dissimilarity of tax bases, they also react disparately to GDP movements (refer to Figure 4). Regarding property taxes, by and large SNGs rely on recurrent taxes on immovable property while central governments rely on taxes on financial transactions and inheritance taxes. Similarly, concerning GST/VAT, by and large central governments rely on taxes on production, sales and transfers while SNGs tend to rely more on taxes on the use of goods and on services. These differences in the tax buoyancy for

[27] It should be acknowledged that the aggregation of all SNG revenues by tax type (used here to estimate tax buoyancy coefficients) covers all jurisdictions within countries. As a result, buoyancy coefficients are affected by the plurality of the local tax policy and by the different intergovernmental fiscal systems in place across OECD countries (*e.g.,* tax sharing arrangements, intergovernmental transfers, among others).

[28] For property taxes, the median of the distribution of buoyancy coefficients across countries is 1.5 for SNGs and 0.68 for the central government, while for GST/VAT these values are 1.22 and 0.92, respectively.

property taxes and GST/VAT might explain, at least in part, the reason why SNGs tend to have a slightly higher total tax and revenue long-run buoyancy.[29]

36. It is worth noting that buoyancies do not control for tax policy changes, and, therefore, changes in the assignment of revenues across levels of government. Hence, when such an event happens in the period in which the buoyancy is estimated, the estimated buoyancy coefficient will embed an assumption that these policies are repeated in the forecasting period. For instance, in case taxes were decentralised during the period in which the buoyancy was estimated, this decentralisation might lead to a larger buoyancy for SNGs and a smaller one for central governments (increases/decreases in SNG/central government revenues as a result of decentralisation will be captured by the buoyancy coefficient).

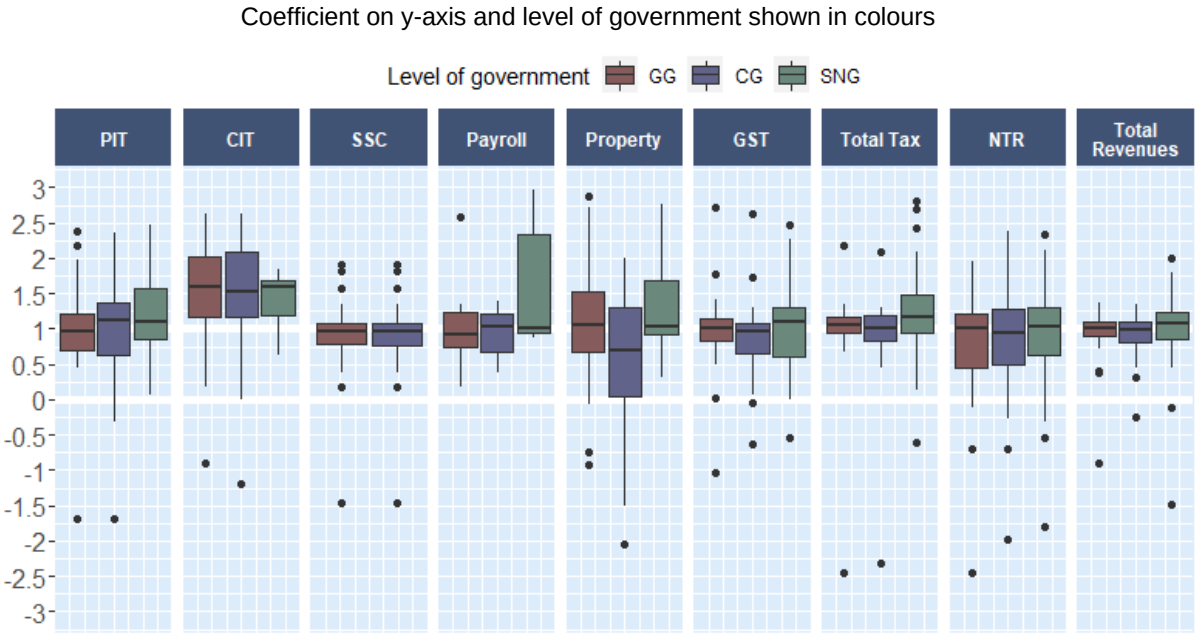
37. Although most buoyancy estimates are clustered around unity, which is the theoretical expectation, there are a large number of outliers. Long-run buoyancies far larger than one (*e.g.,* more than three), and those very close to zero or even negative are unrealistic as they cannot be maintained in the long term (for instance, large long-run buoyancies would make tax revenues increase at such a pace that they would surpass GDP in some decades, and negative long-run buoyancies indicate that the higher the GDP growth in the long-run the lower the revenues from the tax). Therefore, these buoyancies captured movements in revenues that are unlikely to be repeated in the future.[30]

38. As a result of the fact that changes in the assignment of revenues across levels of government and changes in tax policies are not controlled for when estimating buoyancies, the easiest way to minimise the extent to which these effects are captured by the buoyancy coefficient and reproduced in the forecasts is by using total revenues from the general government (see the last column of Figure 9, general government total revenues are by and large the distribution with the least dispersion and whose values are closest to unity). That is because the general government captures all levels of government in aggregate and, thus, this averages out effects from changes in the assignment of revenues across levels of government. In addition, as general government revenues aggregate the revenues from all tax types and levels of governments, reforms of specific jurisdictions or even the central government will have a smaller impact on the general government revenue in comparison to the impact on the respective level of government that made the reform.

[29] It is worth noting that payroll taxes also tend to be slightly more buoyant at the subnational level but as the share of payroll taxes as a percentage of total taxes is rather small (refer to Figure 3), its impact on total taxes and revenues are likely to be non-significant.

[30] As the data is more stable at the general and central government level, for no country was the total revenue buoyancy below 0.39, or higher than 1.4, with the exception of Mexico, for which a negative buoyancy coefficient was estimated. At the SNG level, examples of extreme buoyancies for total government revenues are Denmark, Ireland and Norway (negative coefficients), as well as Hungary (18.3).

Figure 9. Distribution of long-run buoyancy coefficients of the ECM model by level of government and type of revenue across OECD countries



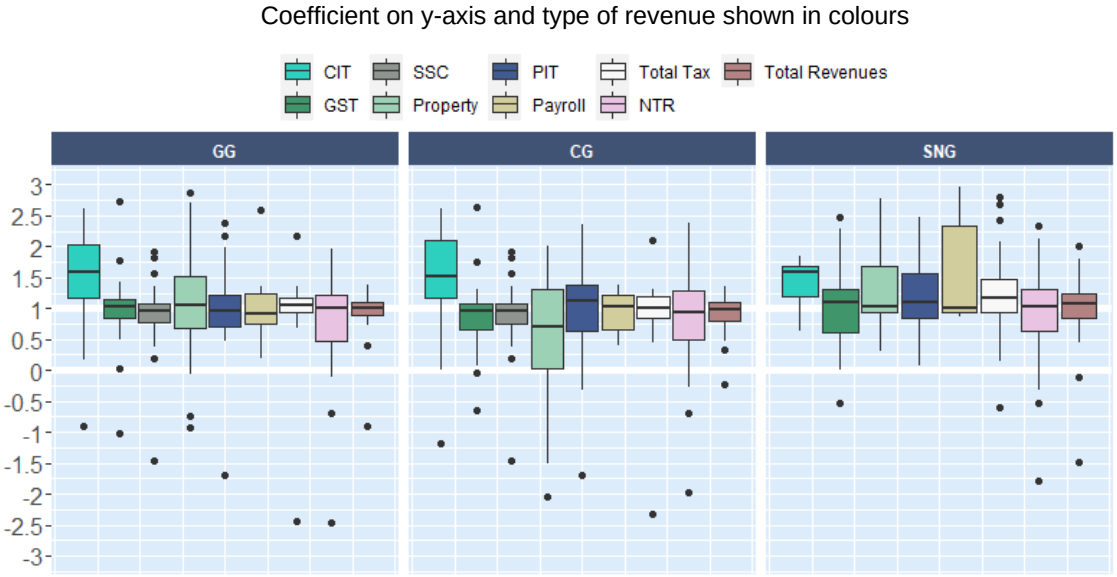
Note 1: For visualisation purposes values are capped between -3 and +3. GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. Recall that a buoyancy of "x" means that an increase in GDP growth of "y%" will lead to an increase of revenues of "x·y%". PIT, CIT, SSCs, GST/VAT and NTR refer to personal income tax, corporate income tax, social security contributions, good and service tax (or value added tax) and non-tax revenues.
Note 2: Although rare, in some cases the revenues for some taxes and levels of government were very erratic, with no discernible relation with GDP. In these cases where there is no long-run relationship between variables, an ECM should not be used as it can lead to misleading and unrealistic results. This is usually the case when coefficients are significantly above one or below zero (although in some cases negative buoyancy coefficients may simply imply a deliberate policy that reduced tax revenues in the long-run while GDP grew).
Note 3: As explained in Section 2.4, non-tax revenues are estimated by taking the difference between government revenues from the OECD SNA and tax revenues from OECD Revenue Statistics, which results in unconsolidated values (*i.e.*, some tax revenues that are collected by the central government and transferred to SNGs are counted both as central government tax revenues and SNGs' intergovernmental grants, which are classified as non-tax revenues). For further discussion on data consolidation in the context of the fiscal impact of population ageing across levels of government, see de Biase et al. (2022), notably its Annex D.
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

39. Figure 10 shows the same data as Figure 9, except the types of tax are coloured, separated by levels of government. With this different visualisation other insights become clearer. First, CIT is notably the most buoyant type of revenue source, which indicates that governments that rely more on CIT are expected to enjoy more revenues in the future in case these patterns from the past continue.[31] Second, SSCs seem to be among the least buoyant tax type for the general government, as its distribution overlaps with the bottom half of the distributions of other types of revenue sources (except for CIT, for which there is no clear overlap). Third, for the general government, the medians of all other types of revenues are pretty close to one another and to unity while for central governments and SNGs the median of the distributions tend to vary relatively more widely as there is more dispersion.

[31] It is worth noting that in case the COVID-19 crisis leads to substantial changes in the reaction of government revenues to movements in GDP, these buoyancies will be biased. This is a problem that forecasters face when they use any method that is based on past data to forecast the future.

40. As a robustness check, we compared our buoyancy coefficients with the coefficients of other studies and our results are largely consistent with the recent literature. For instance, Belinga et al. (2014) found a long-run tax buoyancy at the general government level of 1.26 for CIT revenues, while for SSCs, PIT and GST/VAT the coefficients were close to unity[32] (on average); Dudine & Jalles (2017) estimated that the long-run buoyancy in a large pool of countries for CIT revenues is 1.5, while for PIT, GST/VAT and SSCs the coefficients were between 0.9 and 1.0; Mourre & Princen (2015) computed the long-run tax elasticities across EU countries and found that the average coefficient for CIT is 1.48 while for SSCs, PIT and GST/VAT values are between 0.9 and 1.1; Deli et al. (2018) estimated an average CIT buoyancy in OECD countries of 1.16, higher than overall tax buoyancy of roughly 1.0. A notable exception is Lagravinese et al. (2020), who found that long-run buoyancy coefficients are below one for all types of taxes, including CIT, whose buoyancy coefficient was the lowest and significantly below one (0.61). These differences across studies suggest that *there are substantial uncertainties with regard to buoyancy coefficients* as they can vary significantly depending on the model design used to estimate them. Therefore, when forecasting government revenues, one should be cautious with buoyancy coefficients and, ideally, use multiple scenarios for buoyancy in order to take into account uncertainties.

Figure 10. Distribution of long-run buoyancy coefficient of the ECM model by type of revenue and level of government across OECD countries

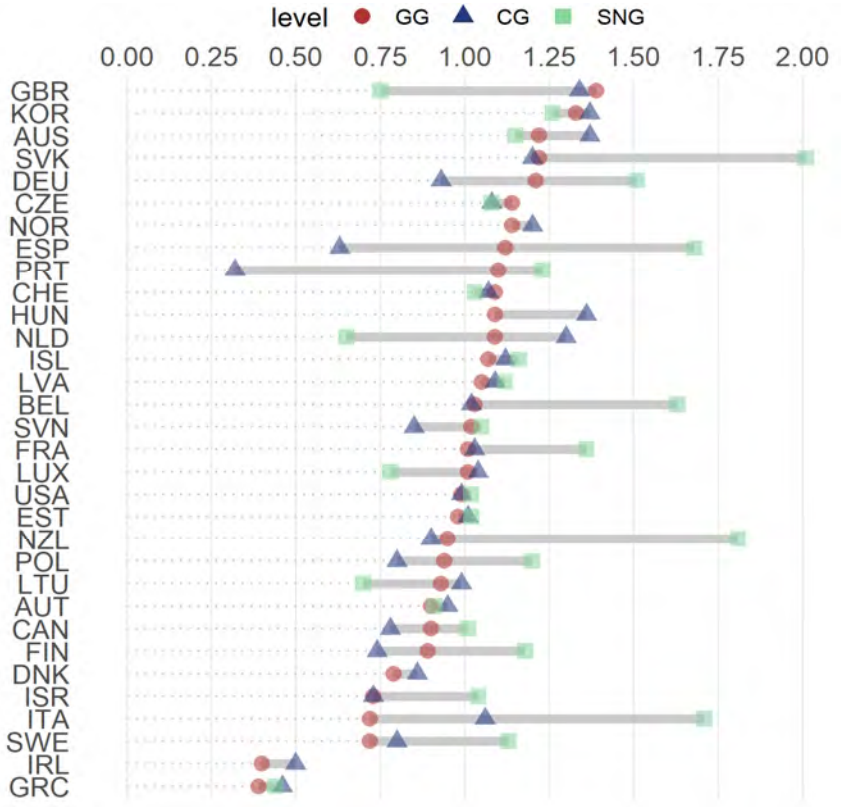


Note: For visualisation purposes values are capped between -3 and +3. Tax types are ordered by the median of general government. GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. PIT, CIT, SSCs, GST/VAT and NTR refer to personal income tax, corporate income tax, social security contributions, good and service tax (or value added tax) and non-tax revenues.
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

[32] This author did not estimate the tax buoyancy for property taxes as defined by the OECD Revenue Statistics and, thus, we could not compare the coefficients for this tax type.

41. Figure 11 depicts the long-run buoyancy for total revenues for each level of government and country. General government total revenue buoyancy varies from 0.39 (Greece) to 1.39 (the United Kingdom), with a median and mean of 1.02 and 0.99, respectively.[33] This proximity to one satisfies theoretical expectations and is in line with the results of other studies (Belinga et al. 2014; Deli et al. 2018; Dudine & Jalles, 2017; Köster & Priesmeier, 2017), but contrasts with the results found by Lagravinese et al. (2020), in which buoyancy coefficients had a tendency to be below unity.

Figure 11. Distribution of long-run buoyancy for general governments' total revenues across OECD countries



Note: GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. Countries are ordered by general government's buoyancy. Values capped between 0 and 2 for visualization purposes.
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

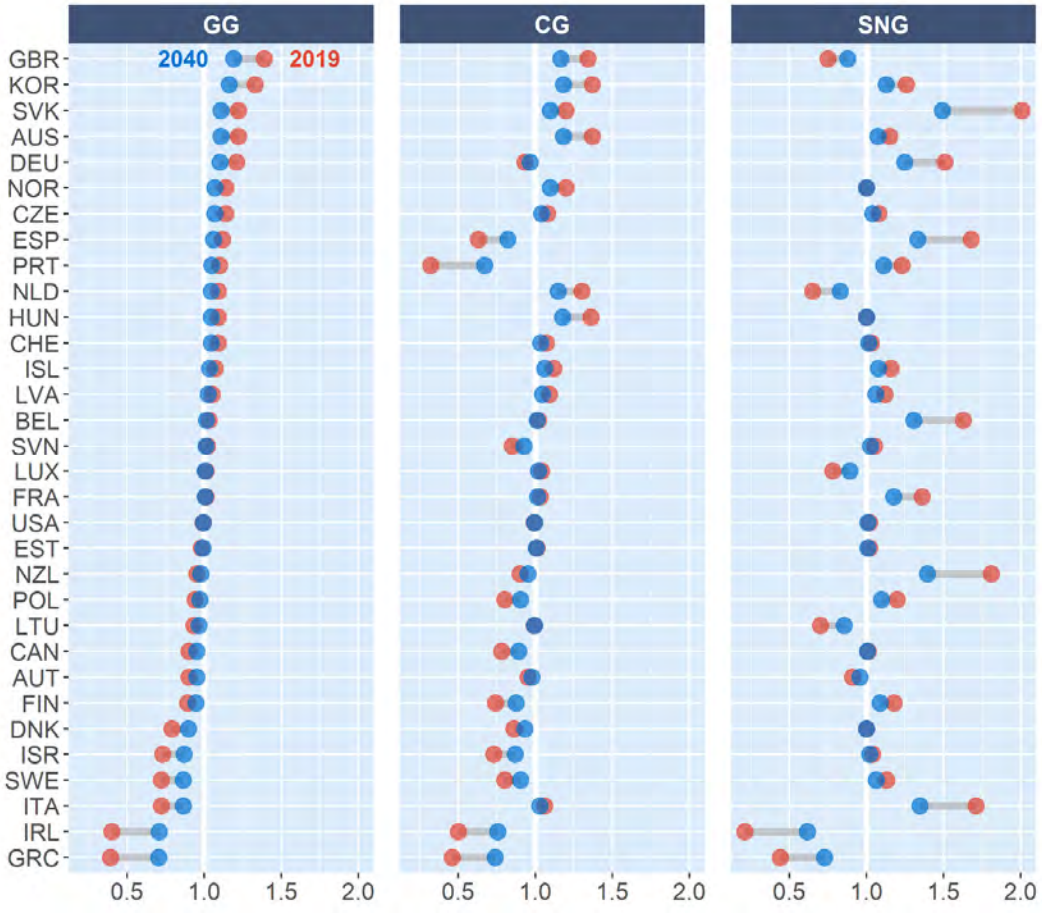
42. The main conclusions presented in this section are robust to outliers and do not change substantially when controlling for the maximum statutory tax rate. Controls for tax rates were employed for central governments and SNGs' PIT, CIT and SSC revenues. Buoyancy coefficients estimated by the model with controls were slightly higher than that of the baseline model. This difference indicates that adjustments in tax rates might have been correlated with GDP in the period analysed. Again, when controlling for tax rates, this result is largely consistent with other estimates. Belinga et al. (2014), when contrasting PIT's long-run buoyancy with a model that controls for top tax rates found the same result – an increase in the long-run coefficient. Deli et al. (2018) also performed the same comparison for PIT and CIT and also found a slight increase in the coefficients when controlling for tax rates.

[33] Statistics were calculated considering all countries except Mexico, whose government revenue buoyancy was negative.

43. One caveat is that despite the fact that the overall conclusions regarding the comparisons between the buoyancy coefficients across levels of government and revenue items still hold when using a robust regression to estimate coefficients and when controlling for tax rates, the 95% confidence intervals for buoyancy coefficients are, for some countries, large. See Annex B for more details on these robustness checks and on the confidence interval values.

44. Before moving into the buoyancy effect on government revenues in 2040, it is worth showing the path of convergence of the buoyancy coefficients from the convergence to unity scenario (3rd scenario). As the convergence to unity scenario assumes a convergence in roughly 40 years (until 2060), the buoyancy coefficients are not going to converge to one throughout the forecasting period (until 2040). The buoyancy coefficients in 2019 are the same displayed throughout this section as they refer to the buoyancy computed for the baseline scenario (the starting point before gradual convergence kicks in under the 3rd scenario). It is interesting to note that in case buoyancy coefficients were to converge to unity in 2040 (instead of in 2060, as in scenario 3), as most buoyancy coefficients are close to unity before any convergence kicks in, there would be no significant difference for most countries.

Figure 12. Distribution of revenue long-run buoyancy across levels of government in the convergence scenario across OECD countries



Note: GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. Extreme buoyancies (below 0.3 or above 2.5) were converted to the value closest to unity in the buoyancy coefficient's confidence interval. This occurred only for the revenue buoyancy of SNGs from Denmark, Ireland, Hungary and Norway.

Source: Authors' elaboration based on OECD Revenue Statistics, OECD System of National Accounts and Guillemette & Turner (2021).

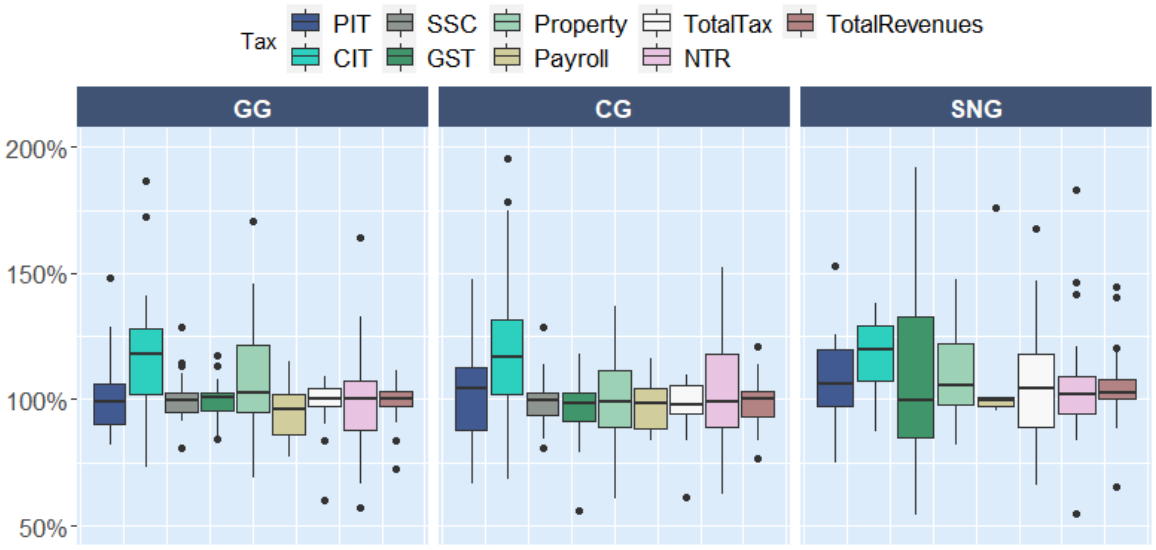
3.6. Buoyancy effect on government revenues in 2040

45. By applying these buoyancy coefficients to the potential GDP, estimated by multiplying the GDP per capita of the OECD Economics Department's long-term scenario[34] to the expected population size, it is possible to have an estimate of the cumulative effect of buoyancy on governments' revenues in 2040.

46. Figure 13 shows the forecasted government revenues-to-GDP ratios by revenue source and level of government in 2040 (100% means that the growth in revenues is the same as the growth in GDP). For all taxes except CIT, the median increase in tax revenues is in line with the increase in GDP growth – for the general government the expected change in this ratio varies from a 4% decrease (payroll taxes) to 1% increase (property taxes) while the CIT revenues-to-GDP ratios are expected to grow by 11%. Regarding levels of government, SNGs' total revenues-to-GDP ratios are expected to grow 3% while central and general governments' revenues are expected to grow roughly the same as GDP growth.

47. It is worth noting that in case these overall tendencies in tax revenues do occur in the future, it will lead to a change in countries' tax composition. Revenues from taxes with a higher long-term buoyancy, such as CIT and property taxes, could be expected to represent a higher share of total revenues. In contrast, revenues from less buoyant taxes, such as SSCs and GST/VAT, could be expected to represent a lower share of total revenues in the future.

Figure 13. Government revenues-to-GDP ratio growth through 2040



Note 1: GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. For visualisation purposes, only observations for which the estimated buoyancy was above -1 and below 3 are shown. PIT, CIT, SSCs, GST/VAT and NTR refer to personal income tax, corporate income tax, social security contributions, good and service tax (or value added tax) and non-tax revenues.

Note 2: Values from the first scenario, which is the one that the estimated buoyancy is used throughout the whole forecasting period.

Source: Authors' elaboration based on OECD Revenue Statistics, OECD System of National Accounts and Guillemette & Turner (2021).

[34] Based on the OECD Economics Department time series of potential GDP per capita (Guillemette & Turner, 2021).

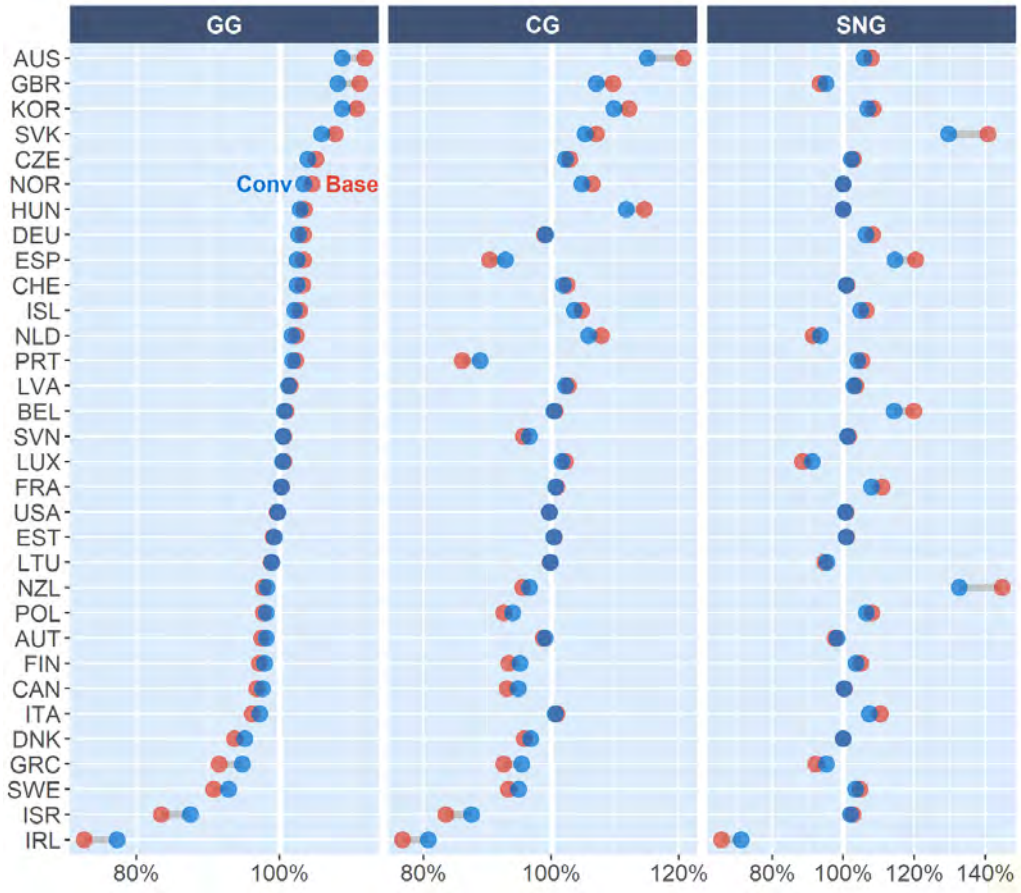
48. One important caveat is that this forecast assumes that the relationship between government revenues and GDP between 1990 and 2018 will be the same through 2040 (the final forecasting year). It is unlikely that this relationship will be precisely the same as there were tax reforms in the last decades that are probably not going to be repeated in the future. For instance, CIT revenues were impacted by rate reductions and base broadening over the last decades. Although rates could continue to decrease, the two-pillar solution to the tax challenges arising from the digitalisation of the economy agreed by 137 jurisdictions of the OECD/G20 Inclusive Framework on BEPS in October 2021, will be expected to attenuate the long-term trend of rate reductions, by introducing a multilaterally agreed floor on tax competition with a global minimum effective tax rate of 15%. On the other hand, while opportunities for tax base broadening remain, it is unclear whether the trend towards base broadening witnessed in recent decades will continue. In relation to taxes on goods and services, in the period after the Global Financial Crisis for instance, countries increased their value added tax rates (*i.e.,* a component of taxes on goods and services) to raise more revenues. However, there are decreasing returns to this approach and countries have largely stopped raising their standard GST/VAT rates. See OECD (2020) for an in-depth and recent analysis of tendencies in taxation across OECD countries.

49. With that said, Figure 14 contrasts the results of the 1st (calculated buoyancy is kept uniform throughout the whole forecasting period) and 3rd (buoyancy coefficients converging to unity in 2060) scenarios on government revenues. The results of the 2nd scenario (unitary buoyancy) are not shown as they were defined as 100% (the increase in government revenues was defined to follow GDP growth). One interesting conclusion that can be drawn from Figure 14 is that, for most combinations of countries and levels of government, there is no significant difference between the two scenarios. There are only a few exceptions, and these refer to combinations of countries and levels of government for which buoyancy coefficients are more extreme, such as SNGs in the Slovak Republic and New Zealand and central governments in Ireland[35] and Israel.

50. This reveals how insensitive forecasts are to scenarios with buoyancy convergence. If buoyancy coefficients were converging to unity in 2040 (instead of in 2060 as in scenario 3) then the only difference would be that the blue dots in Figure 14 would have been a bit further away from the red dots. More precisely, the average difference in government revenue-to-GDP ratios between a scenario with buoyancy coefficients converging to unity in 2040 instead of in 2060 for the GG, CG and SNG levels of government is -0.08%, -0.13% and 1.09%, respectively.

[35] Note that for Ireland, using a GNI* series in place of a GDP series results in less extreme buoyancy estimates. This is being explored in subsequent country case studies.

Figure 14. Government revenues growth through 2040 (as a % of potential GDP growth)



Source: Authors' elaboration based on OECD Revenue Statistics, OECD System of National Accounts and Guillemette & Turner (2021).

Note: GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. "Conv" and "Base" refers to the convergence to unity and baseline scenario, respectively.

4. Impact of population ageing on government revenues

4.1. Population ageing and government revenues

51. Population ageing affects government revenues through at least two different means: firstly, by affecting overall economic activity (*i.e.,* expected GDP growth), which is intrinsically linked to government revenues, and secondly by affecting tax bases.

52. Theoretically, Rouzet et al. (2019) explains that the net effect of ageing on economic growth is uncertain, as it will depend on: 1) declining employment to population ratios, 2) rising capital per worker, and 3) productivity growth. The latter effect varies based on human capital investments, innovation, and technology adoption. As these factors differ across countries, so do the population ageing effects.

53. Empirically, the literature regarding the net overall effect of population ageing on economic activity is inconclusive. Maestas et al. (2016) estimated the elasticity of GDP growth with respect to ageing in US states and concluded that, as a result of slower growth in labour productivity and the workforce, a 10% increase in the fraction of the elderly (over 60 years old) decreases GDP growth in per capita terms by 5.5%. In the same vein, Daniele et al. (2020) concludes that in many regions actual productivity growth

has been lower than that required for population ageing to have a neutral effect on per capita GDP levels. Acemoglu & Restrepo (2017), on the other hand, found that there is no negative relationship between population ageing and GDP growth in per capita terms, possibly because of an endogenous response of technology related to a faster adoption of robots by countries undergoing a more rapid ageing population.

54. Regardless of the net effect on economic activity, authors usually agree that population ageing will affect economic aggregates unevenly. As explored in the previous section, countries and their respective levels of government rely to a varying degree on a myriad of tax bases. Thus, even neutral shifts in economic activity caused by population ageing can affect government revenues in a non-neutral manner depending on its reliance on certain tax bases. A decrease in the workforce and a potential increase in productivity as a result of rising capital per work and of technology advancements are unlikely to have a neutral effect on government revenues. For instance, Colin & Brys (2020) argue that population ageing is likely going to lower revenues from taxes on labour such as PIT, SSCs and payroll taxes, as a result of smaller workforces and lower incomes, more from pensions rather than wages. Nevertheless, the authors highlight that automation might increase wages, potentially minimising these negative impacts.

55. As GDP growth is a determining factor of government revenues and expenditures, it is challenging to forecast these without having a GDP forecast. For that purpose, this paper draws on Guillemette & Turner (2021), who estimated the impact from population ageing on GDP per capita by considering four elements: a metric for living standards, productivity, capital intensity and labour utilisation. They concluded that although real GDP per capita is expected to grow in the upcoming decades, its growth will be slower than what we observed in the past as a result of, among other reasons, a decrease in the working age population share.

4.2. National Transfer Accounts (NTA)

56. There has been a growing interest in the impact of population ageing on economic aggregates. The United Nations (UN) assigned to a team of more than 50 researchers from 23 different countries the task of building a dataset with age profiles for aggregates from the System of National Accounts – the National Transfer Accounts (NTA)[36]. The European Union (EU) also joined this project and helped in the making of such a dataset but for EU countries[37].

57. More precisely, the NTA's goal is to enhance our understanding of the economic consequences of demographic changes by incorporating demographic information into the System of National Accounts (SNA). The NTA are based on data gathered from household surveys (*e.g.,* living standard surveys, labour surveys, among others) and from government agencies (*e.g.,* pension, health expenditure, among others). As the information is available at different levels of resolution depending on the country and source, the research team treats these data to harmonise them, which is a complex process involving assumptions and quantitative methods.[38]

4.3. The effect of population ageing on government revenues using NTA

58. The NTA data provide an age profile for economic aggregates. Thus, it is possible to estimate the impact of population ageing on certain taxes or tax bases through the following equation:[39]

[36] More information on the UN NTA project can be found at https://www.ntaccounts.org/web/nta/show.

[37] More information on the European NTA project can be found at http://dataexplorer.wittgensteincentre.org/nta/.

[38] More information on the procedures used can be found at United Nations (2013).

[39] Other studies that followed a similar approach are Kim & Dougherty (2020), Prammer (2019), Williams et al. (2019), Felix & Watkins (2013) and Creedy et al. (2010).

$$\Delta R_{c,i} = {\sum_a p_{c,i,a} r_{c,b,a}} \Big/ {\sum_a p_{c,b,a} r_{c,b,a}} - 1 \qquad (2)$$

59. Where ΔR refers to the growth rate for a government revenue item or a proxy for it (*e.g.,* a tax base in the case of taxes), p to the population and r to the respective revenue item or its proxy on per capita terms. The subscripts c, i, b and a refer to the country, the current year of the forecast, the base year of the forecast and the age group, respectively. It is worth noting that this equation has $r_{c,b}$ both in the numerator and denominator, which means that it assumes that the age profile remains constant over time, an assumption that seems to be plausible in relatively short periods of time (such as less than 20 years) and, thus, for the purposes of this paper (see Annex C).

60. By using this equation, cross-country differences with regard to demography and age profiles are fully taken into account. Regarding demography, the timing and scale of population ageing differs across OECD countries, with some countries enjoying an increase in the adult population (*e.g.,* Mexico) while others a decrease (*e.g.,* Japan), impacting, for instance, the workforce and the age dependency ratio of these countries in a distinct manner.[40] Due to these differences, population ageing is expected to have heterogeneous effects on economic activity and government revenues. Age profiles are also expected to vary across countries as factors that differ across countries such as education, work experience, health, wealth, among others, impact the decisions of individuals related to the amount of time at each age they work and to their consumption patterns.[41]

61. Another implication of using this equation to estimate the impact of population ageing on government revenues is that $\Delta R_{c,i}$ captures two different effects: the change in the size of population and the change in the structure of population. The first effect occurs when $\sum_a p_{c,i}$ (the population in the year of the forecast) is different than $\sum_a p_{c,b}$ (the population in 2018). Assuming no differences in the structure of the population (*i.e.,* age profiles are the same across age groups), equation 2 would yield exactly the expected population growth. The second effect is a consequence of the fact that age profiles differ across age groups. Assuming that there is no change in the size of population (*i.e.,* $\sum_a p_{c,b} = \sum_a p_{c,i}$), changes in the distribution of the population across age groups (a) would lead to a change in government revenues (*e.g.,* older people tend to have more asset income and less labour income and, thus, everything else held constant, the older the population the higher government revenues from taxes on asset`s income and the lower revenues from taxes on labour income).

62. In order to apply equation 2 to OECD countries, data from the NTA UN and from the NTA EU are used. In this paper, data from NTA EU was preferred as the NTA EU focuses more on comparability across countries than NTA UN.[42] As this study focuses on contrasting the impact of population ageing across countries, we chose to use the data from NTA EU when available. When not available, the most recent data from NTA UN was used. In addition, both NTA EU and UN have no data on some OECD countries. In these cases, the average data from a cluster of countries was used as a proxy (this process is further explained in Annex D).

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[40] Population forecasts were obtained in June 2021 from OECD Demography and Population Statistics and, thus, all factors that drive demography (*e.g.*, fertility rates, life expectancy, migration, among others) are captured. For detailed and country-specific assumptions used in the demographic forecasting, see "Historical population data and projections (1950-2060)" from OECD Demography and Population Statistics.

[41] Mason & Lee (2011) suggests that people choose "to work an amount of time at each age that equates the marginal utility gained from labour income to the marginal utility lost from reduced leisure time, balancing these also against expected returns to investment in education and work experience", and "many factors, such as education, experience, health, and vitality, affect productivity and vary over the lifecycle".

[42] See http://dataexplorer.wittgensteincentre.org/nta/.

63. Table 1 summarises the variables in the NTA EU that can work as a proxy for governments' revenue items ($r_{c,b}$ in equation 2). The NTA Manual argues that these variables are good proxy for tax revenues: *"taxes on income and payrolls can be assumed to have the same age pattern*[43] *as labour income; taxes on assets can be assumed to have the same age pattern as private asset income; taxes on consumption such as value added taxes (VAT) or sales taxes can be assumed to have the same age pattern as total private consumption"* (United Nations, 2013). For instance, assuming that taxes on income have the same pattern as labour income means that we are assuming that the distribution of the amount of labour income received over the life cycle is the same as the distribution of the amount of income taxes paid over the life cycle. That is, often people pay more/less income taxes in the same age that they receive more/less labour income.

64. It is worth noting that when using the tax base to forecast the impact of population ageing on tax revenues, it is implicitly assumed that tax rates are constant for different age groups. For instance, for income taxes this means that an increase in the income of a certain group of people will lead to the same increase in tax revenues, regardless of the age group of these people. As OECD countries tend to have progressive tax systems, such an assumption of constant tax rates across age groups will tend to generate smaller estimates of tax revenues when an age group with higher earners is growing (*e.g.,* people in their late 40s) and larger estimates of tax revenues when an age group with low earners is growing (*e.g.,* the elderly).[44] In a similar vein, for consumption taxes this assumption means that it is assumed that tax rates applied to the basket of products consumed by people from each age group are the same.

65. In the NTA UN and EU there is no age profile that can be easily used to estimate the age profile of property tax revenues. Although the NTA UN computes age profiles for property tax revenues for seven OECD countries,[45] the NTA EU does not. As the number of OECD countries for which there is an age profile for property tax revenues estimated by the NTA UN is small (only 7), for enhancing cross-country comparison, property tax revenues were considered to be invariant to population ageing.[46]

66. It is worth noting that as older people tend to be asset rich and income poor, they tend to pay more recurrent taxes on immovable property as a share of the income than younger people. Thus, as recurrent taxes on immovable property revenues are among the most important sources of property tax revenues, the latter tend to increase with population ageing, everything else held constant (see, for instance, Williams et al., 2019). And as property taxes are often substantial only for SNGs (refer to Figures 2 and 3), the most likely consequence of this assumption is to underestimate SNGs revenues in the long run, while central and general government's revenues are unlikely to be affected significantly by any change in property taxes, as they represent a small share of their revenues (see Figure 2).

67. Revenues under the heading of "non-tax revenues" and "other taxes" are also considered to be invariant to population ageing. That is because they encompass a large variety of revenue sources and, thus, no single or trivial combination of variables in NTA EU or UN could be used as a proxy for them.

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[43] Age pattern for an aggregate refers to the distribution of economic/fiscal aggregates over age groups.

[44] This report also disregards tax policies aimed at some specific age groups, for instance, tax credits targeted to older workers (for an overview of these policies, see OECD, 2011).

[45] Colombia, Finland, Mexico, Slovenia, South Korea, Sweden and the United States.

[46] This means that the age profile for all age groups is the same. This does not mean that $\Delta R_{c,i} = 0$. That is because equation 2 will still capture the effect of population growth.

Table 1. Classification of revenue sources and their respective bases/proxies in NTA

Source	Reference	Revenue item	Main tax base(s) or proxy(ies)	Variable in NTA EU
OECD Revenue Statistics	1100	PIT	Income and capital gains	Labour income
	1200	CIT	Profits and capital gains	Private asset income
	2000	SSC	Payroll	Labour income
	3000	Payroll taxes		
	4000	Property taxes	Asset values, transactions and wealth	-
	5000	GST	Production, sale, transfer, leasing and delivery of goods and rendering of services	Private consumption
	6000	Other xaxes	Not applicable - encompass different revenues	-
OECD Revenue Statistics and SNA	SNA's government total revenues - OECD Revenue Statistics' Total taxes	Non-tax revenues		-

Note: In some cases, there are more than one estimation for the same variable, year and country – in these cases, the most recent estimation was used. For the NTA UN the "smoothed mean" age profile was used.
Source: Authors.

68. Lastly, regarding population projections ($p_{c,i}$ in equation 2) data from the OECD Demography and Population was used. This dataset has data on the population segregated by age group until 2060. As each group represents five ages (*e.g.,* from 0 to 4 years old, 5 to 9, 10 to 14 and so forth) and as the NTA data has information for every age (*e.g.,* 0, 1, 2, 3, 4 years old and so forth), it was necessary to make some adjustments to make these data compatible with one another. For that purpose, we assumed that the number of people is distributed uniformly within each age group. In addition, the last group of the OECD dataset refers to people older than 85 years old whereas the NTA UN and EU datasets have individual ages until 90 and 80 years old, respectively. Thus, to make the OECD population projections compatible with the NTA data, the age profile of all people older than 85 and 80 years old was assumed to be the same as the age profile of 85- and 80-years old people for the NTA UN and EU, respectively.

4.4. Age profiles

69. Before delving into the results of the estimates of the impact of population ageing on government revenues (application of equation 2), in order to better understand and interpret the estimates, it is worth looking at the age profiles for labour income, private asset income and private consumption. Figure 15, below, reveals the age profile for these three tax bases. The following conclusions can be drawn:

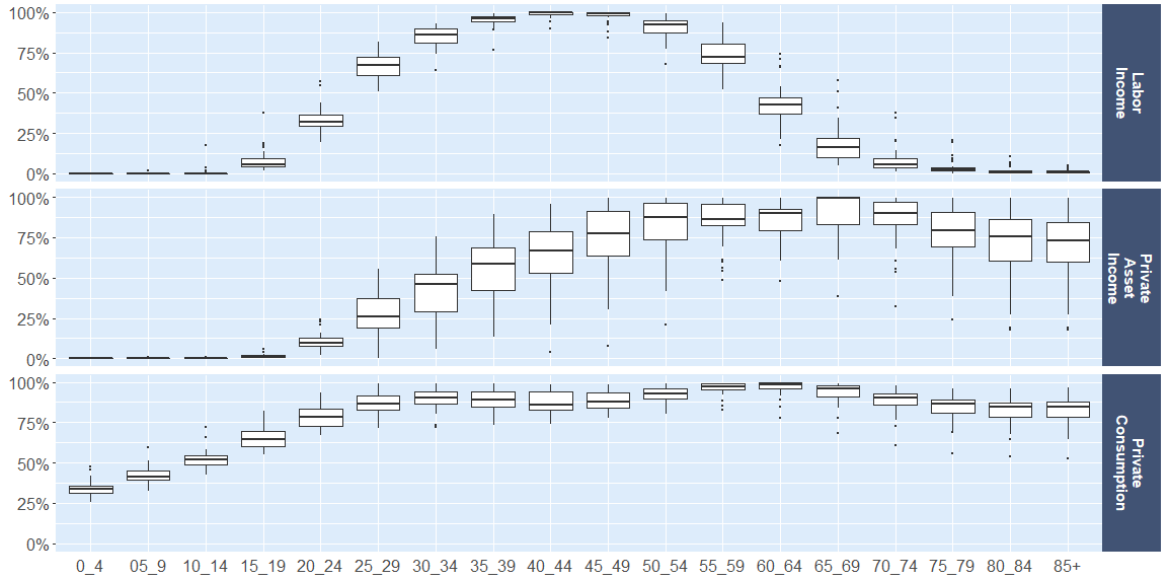
- *Labour income*:[47] Increases slowly when people are in their mid-teenage years (i.e. from the age of 15 onwards), peaking in their 40s and, then, decreasing rapidly from their 50s until their 80s. Notably, the dispersion across OECD countries is rather small, which shows that this pattern is similar across countries. Therefore, countries in which the expected average age of the population over the next 20 years pass through the 40-54 age group are expected to enjoy an increase in aggregate labour income. Older countries, on the other hand, are expected to experience a decrease in aggregate labour income as the proportion of people over 50 years old grows.
- *Private asset income*: Increases slowly when people are in their 20s, peaking in their 60s and decreases rather modestly until their 80s. It is interesting to note that people over 85 years old tend to have more private asset income than those under 40 years old. The dispersion is, though, rather large as there are countries in which people over 85 years old are in the age group with the highest

[47] Does not include pensions. This might lead to an overestimation of the impact of population ageing on PIT revenues as in some OECD countries pension income is taxed. In other words, the fact that in our model PIT revenues fully reflect labour income without considering pension income attenuates the drop in PIT revenues when people get older.

private asset income while in other countries less than half of them are in the high earning group. As a result, the impact of population ageing on private asset income depends not only on how young the population is but also on the distribution of private assets across age groups.

- *Private consumption*: Increases when people are born until their 30s and stays rather flat from there on. The dispersion is not large, which indicates that this pattern of consumption is similar across OECD countries. Expected demography is, thus, the most important element to estimate the impact of population ageing on private consumption.

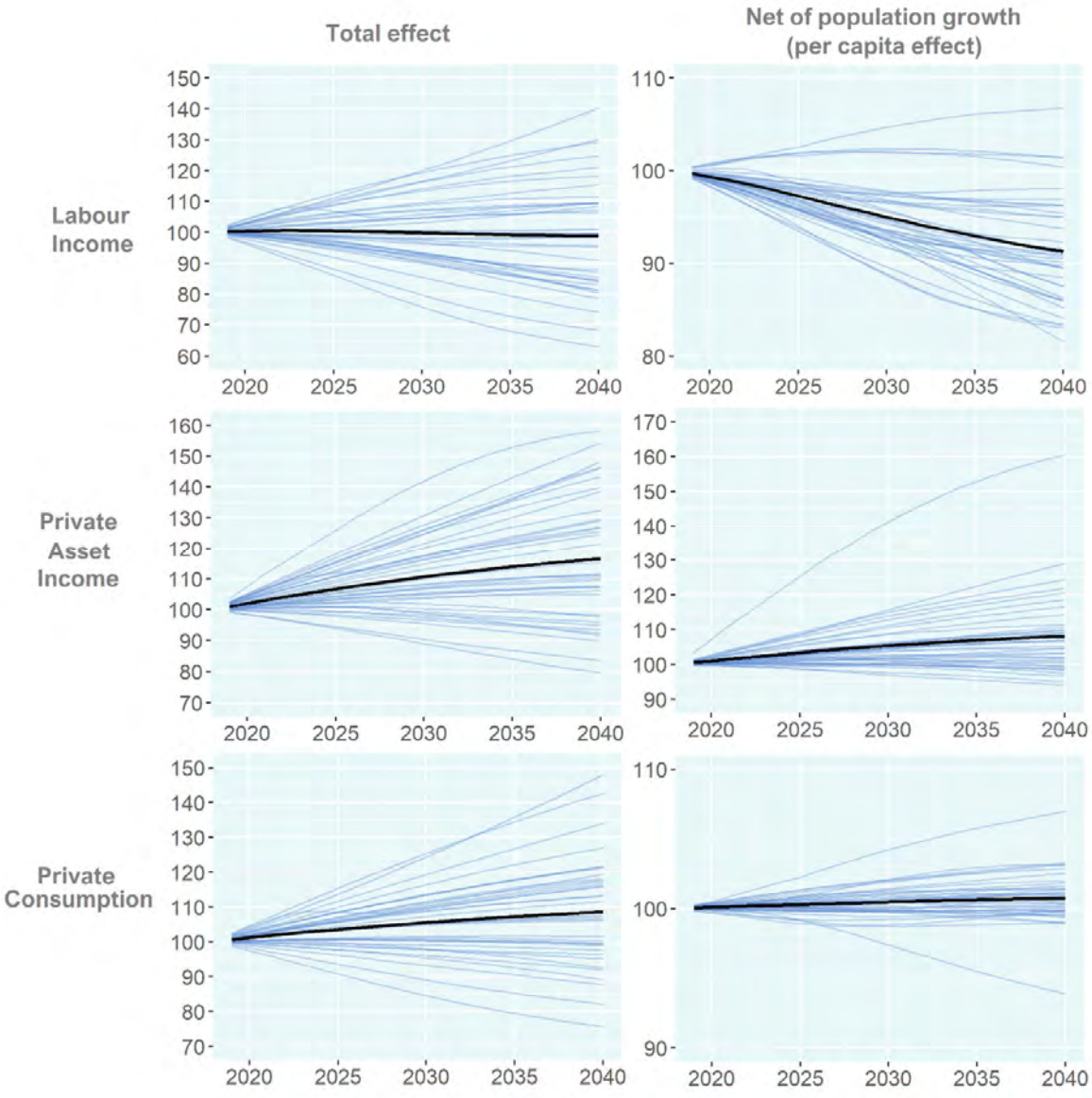
Figure 15. Distributions of age profiles across OECD countries (as a % of the maximum value)



Note: The y axis refers to the value of the respective age group as a percentage of the value of the group with the highest income/consumption while the x axis refers to the age group. Missing values were already inserted (see Annex E for details).
Source: Authors' elaboration based on NTA UN and EU.

70. The estimated impact of population ageing on these three tax bases is shown in Figure 16. Charts on the left-hand side show the population ageing effects in real terms while charts on the right-hand side show these effects on a per capita basis. As the population of many OECD countries are expected to grow between 2018 (base year) and 2040, the application of equation 2 (in real terms) tends to underestimate the negative impact of population ageing on per capita terms (*i.e.,* the negative impact from changes in the age profile are offset by the increase in population).

Figure 16. Impact of population ageing on tax bases (base 100 in 2018)



Note: Charts on the left-hand side shows the population ageing effects in real terms while charts on the right-hand side shows these effects on a per capita basis. Black line refers to the OECD average while blue lines refer to OECD countries.
Source: Authors' elaboration based on NTA UN, NTA EU and OECD population projections.

71. These estimations show that 45% of OECD countries are expected to have a positive impact from demographic changes on labour income but, on per capita terms, this proportion shrinks to 8% (or only 3[48] out of 36 countries). This means that population growth in the next 20 years is expected to raise aggregate labour income but as people get older the average labour income will shrink.

72. In contrast, when it comes to private asset income, only 9 and 10 OECD countries are expected to be negatively affected by changes in demography in real and per capita terms, respectively (these

[48] These countries are Colombia, Mexico and Türkiye.

countries are mostly from central and eastern Europe[49]). A notable exception is Korea, which is expected to enjoy a 50% increase in private asset income on per capita terms due to population ageing – that is because Korea's age profile for private asset income is highly skewed, with older people having far more private asset income than younger groups (see Annex E).

73. Lastly, as aggregate private consumption does not vary wildly by age group once people hit their 20s (refer to Figure 14), the per capita effects of population ageing on private consumption are rather meagre, varying from a decrease of 6% (Korea) to an increase in 7% (Colombia), with all other OECD countries in between -1% and +3%. Thus, effects in real terms can be attributed to, by and large, variations in population size.

4.5. The effect of population ageing on government revenues using NTA

74. Figure 17, Panel A, shows the impact of population ageing on government revenues on per capita terms in 2040, assuming that the impact of population ageing on tax bases is identical to its impact on the respective tax revenues (refer to Table 1). The impact on total revenues was calculated by taking a weighted average of the impact on each revenue item. It is worth recapping that for property taxes, other taxes and non-tax revenues the impact of changes in the structure of the population was assumed to be zero.

75. As expected, revenues from taxes based on labour income (PIT, SSCs and payroll) are the most negatively affected while CIT revenues, which are based on private asset income, are expected to increase in most OECD countries. As CIT revenues are significantly smaller than those from PIT, SSCs and payroll taxes (refer to Figure 2), when considering population ageing effects alone (no buoyancy effects), total government revenues are expected to decrease in most countries on a per capita basis.

76. When it comes to the total impact from population ageing (Figure 17, Panel B) as a result of the overall tendency of population growth, the population ageing effect becomes positive for most taxes and countries. The exceptions are taxes based on labour income (PIT, SSCs and payroll) – according to our forecast 21 out of 36 countries should expect a reduction in revenues coming from these taxes in 2040 due to population ageing (*i.e.,* combined effect of population growth and change in the structure of the population). The total effect for total taxes is positive for most countries (again 21 out of 36) and varies from a decrease of 36.8% in Lithuania to an increase of 40% in Israel.[50]

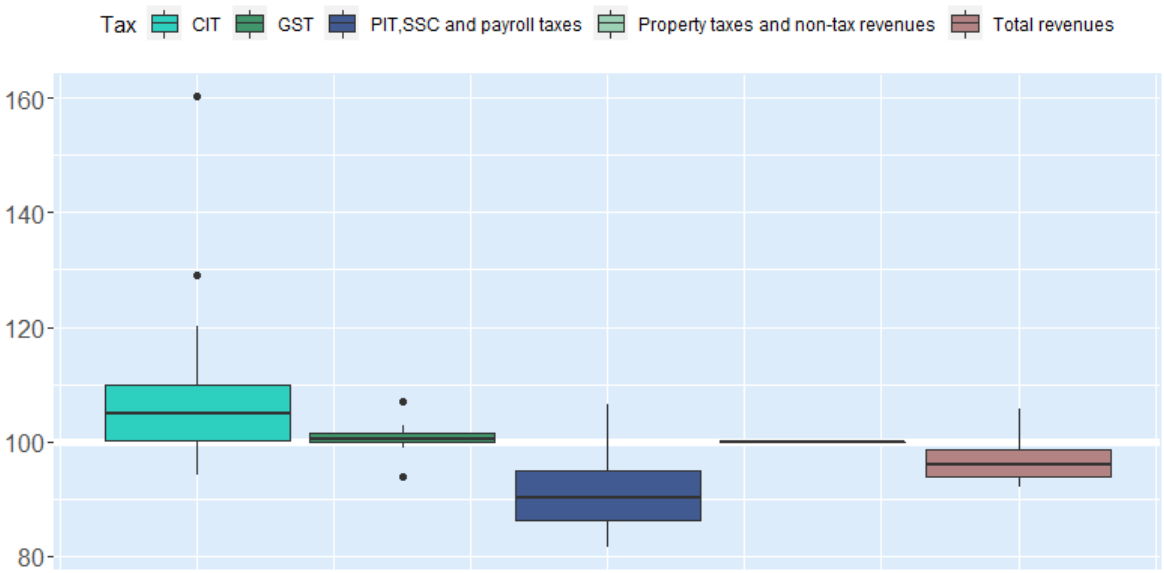
[49] These countries are Czech Republic, Estonia, Greece, Hungary, Japan, Lithuania, Latvia, Poland, Slovakia and Slovenia. Country coverage of 36 out of 38 OECD countries (there was no data available for Costa Rica and Chile).

[50] These differences are explained by cross-country variations in 1) population growth, 2) taxes and 3) age profiles.

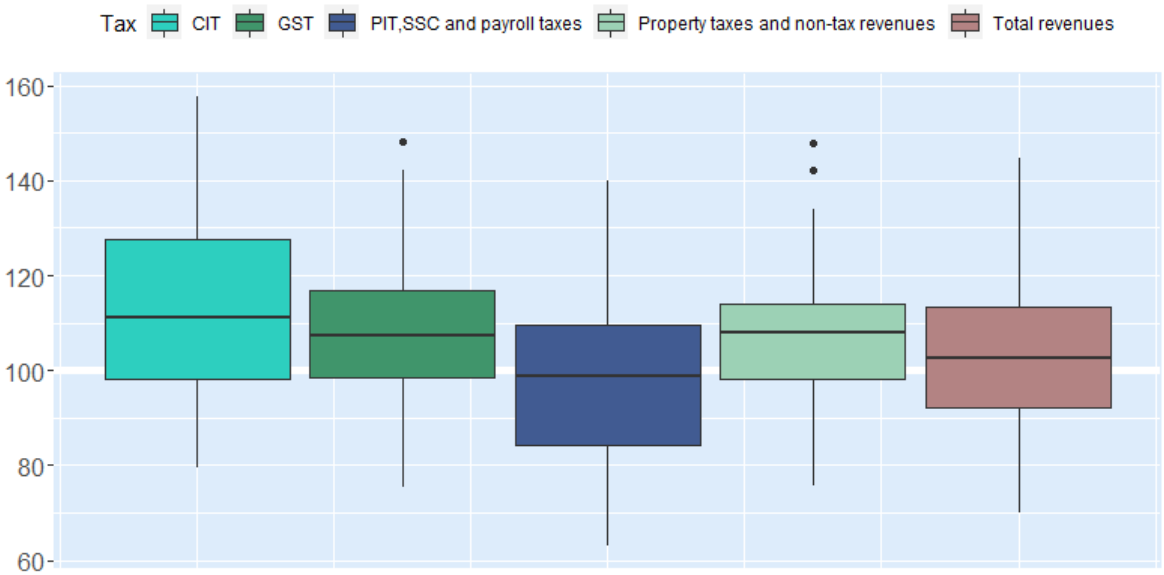
Figure 17. Impact of population ageing on general government's revenues in 2040 for OECD countries

Shown in real terms, per capita with base of 100 in 2018

a. Impact from the change in the structure of the population



b. Total impact from population ageing (population structure and growth)



Note: PIT, SSCs and payroll taxes are impacted identically by population ageing as the same tax base was used for these three taxes.
Source: Authors' elaboration based on NTA UN, NTA EU and OECD population projections.

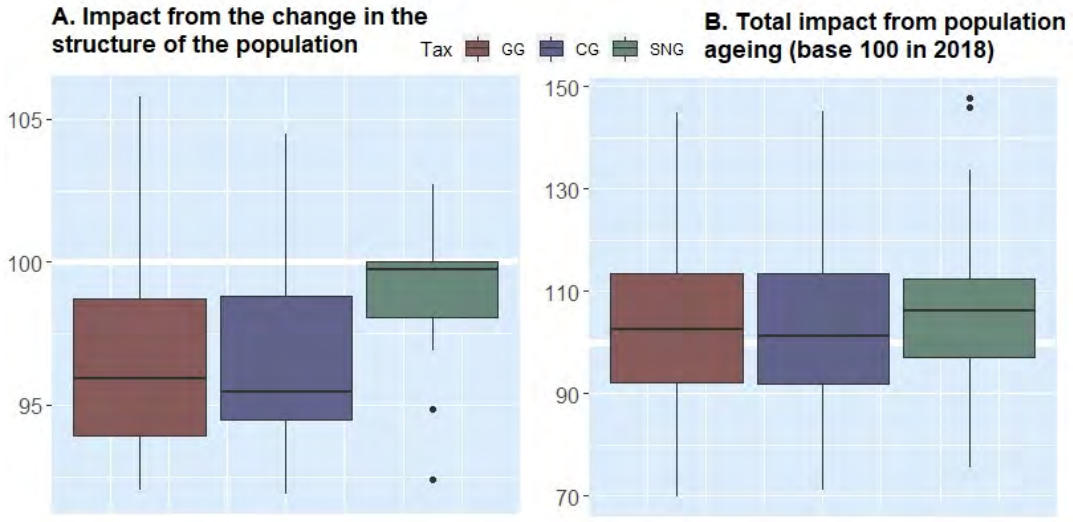
77. Now, looking at levels of government, it is clear that the effect from the changes in the structure of the population are stronger for central government's revenues in comparison to SNGs' revenues (Figure 18, Panel A). That is because by and large central governments' reliance on taxes on labour income (notably PIT and SSCs) are substantially higher than SNGs' reliance on this tax base (refer to Figure 3). Although central governments tend to rely more on CIT, which are by and large positively

impacted by population age, in no OECD country CIT revenues are larger than SSCs' and PIT's revenues combined (by a significant margin). As a result, only in four countries (Mexico, New Zealand, Sweden and Türkiye) the change in the structure of population leads to a positive impact on revenues.

78. Looking at the total impact from population ageing (considering both change in the structure of the population and population growth), this same pattern of central governments being more negatively affected than SNGs is repeated (Figure 18, Panel A). Nevertheless, when considering both effects, due to population growth, the impact is expected to be positive for the central government of most OECD countries (Figure 18, Panel B).

Figure 18. Impact of population ageing on each level of government's revenues in 2040

Shown in real terms, per capita with base of 100 in 2018



Note: The two outliers displayed by the chart are Latvia and Slovenia, both are countries with old populations (the 6th and 8th in population's average age) and in which their SNGs rely substantially on PIT (refer to Figure 2).
Source: Authors' elaboration based on NTA UN, NTA EU and OECD population projections.

79. Finally, Figure 19, below, shows the impact of both population growth and changes in the structure of the population across OECD countries. Many interesting conclusions are worth noting.

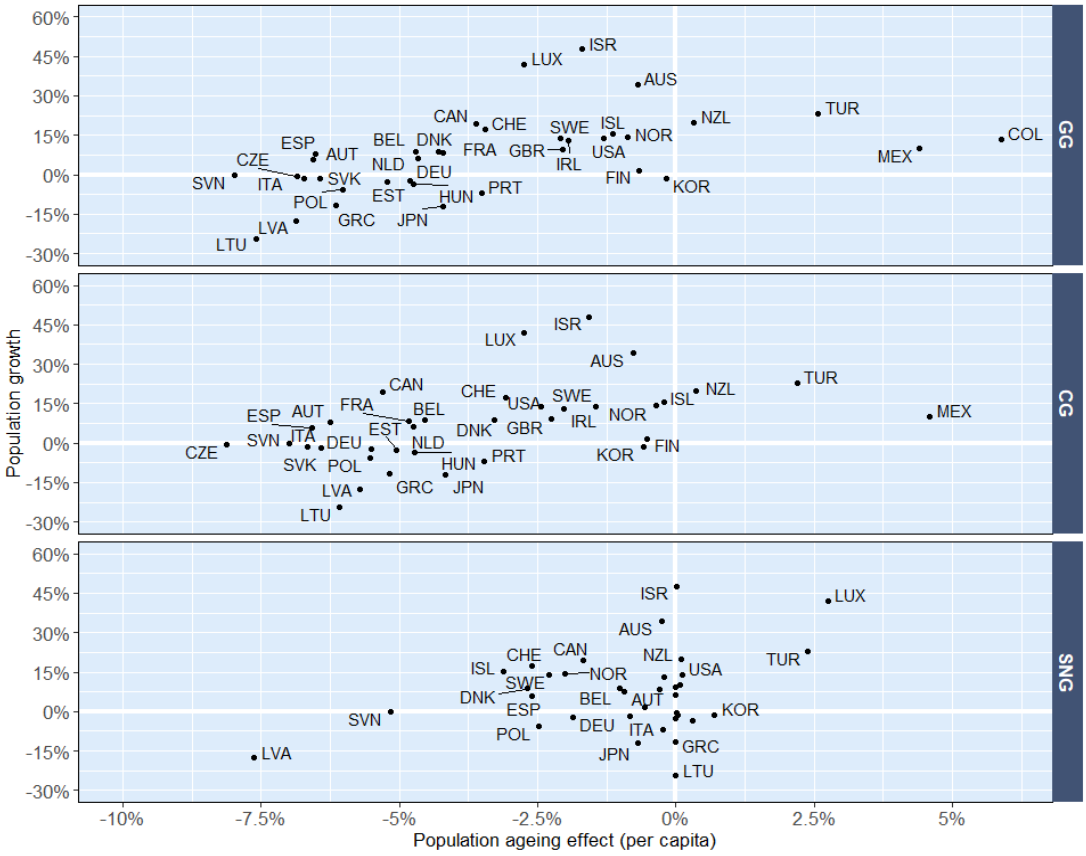
80. First, these impacts are very much correlated. That means that OECD countries that are expecting their population to grow also tend to be less impacted from the change in the structure of the population as, in these countries, a portion of this growth is going to occur in age groups that improve the structure of the population in terms of tax collection.

81. Second, at the general government level, changes in the structure of population tend to have negative outcomes for most OECD countries, except for four younger OECD countries (Colombia, Mexico, New Zealand and Türkiye). When it comes to growth in population, the population is expected to shrink and, government revenues fall, in only 14 out of 36 OECD countries. The effect of population growth is also substantially larger than the effects from the changes in the structure of the population, at least in the forecasting period.

82. Third, although the population growth is the same for all levels of governments, the changes in the structure of the population are significantly more relevant at the central and general level of government. That is because SNGs rely less on revenues that are linked to labour income such as SSCs and PIT.

83. Lastly, with regard to the impact of demography on general government revenues, countries can be grouped into three groups: 1) countries in which population ageing might increase government revenues because of both an increase in the population and changes in the structure of the population (the smallest group with only four countries – Colombia, Mexico, New Zealand and Türkiye), 2) countries in which changes in the structure of population growth will lead to falls in revenues but population growth will offset this effect, which means that per capita effects of these changes are negative but not the real effects (the largest group with half of the 36 OECD countries), 3) countries in which both population will decrease and changes in the structure of the population will lead to a reduction in government revenues (14 out of 36 countries), leading to a reduction in both government revenues in levels and per capita values. The allocation of countries into these groups are clearly correlated with the average age of the population (see Annex F for the average age of each OECD country).

Figure 19. Government revenues growth through 2040 considering the impact of population ageing



Source: Authors' elaboration based on NTA UN, NTA EU and OECD population forecasts.

5. Incorporating buoyancy and population ageing effects

5.1. Methodology for combining the two effects

84. In order to combine the buoyancy and the population ageing effect, the following equation was employed:

$$TR_{c,l,i} = \left(1 + \sum_{a=i}^{n} \Delta R_{c,l,i} * w_{a,l} \Big/ \sum_{a=1}^{n} w_{a,l}\right) / (1 + \Delta Pop_{c,i}) * \left(1 + \Delta GDP_{c,i} * \theta_{c,l,i}\right) - 1 \qquad (3)$$

85. Where TR refers to total government revenues (real terms), ΔR refers to the population ageing effect (as calculated by equation 2), w refers to the portion of total revenues represented by the respective revenue item a, ΔGDP refers to GDP growth in real terms, θ refers to the buoyancy for total government revenues[51] and ΔPop refers to population growth.[52] The subscripts c, l and i refer to country, level of government, and time, respectively. $\theta_{c,l,i}$ only changes with time in the 3rd scenario of buoyancy converging to unity.

86. The division between the population ageing effect and population growth is necessary to avoid double counting the effects from population growth, as those are already captured by GDP growth. As a result, the blue equation can be interpreted as the effect from the changes in the structure of the population while the green equation the total buoyancy effect, considering population growth.

87. Another key point regards the fact that the forecasted potential GDP per capita growth rates were adjusted to consider effects from the expected variations in the share of the active population to the total population (for details see Guillemette & Turner, 2021). As a consequence, both the potential GDP per capita used in the estimation of the GDP growth and the modelled relationship between government revenues and GDP are affected by population ageing. As equation 3 captures the effect from these two potential impacts of population ageing on government revenues, the results presented in the next section can be interpreted as an upper bound of the effect of population ageing on government revenues to 2040.

88. Lastly, it is worth noting that when combining the buoyancy and population ageing effects in this manner it is implicitly assumed that population ageing affects government revenues only through changes in the tax base. In other words, the relationship between tax revenues and tax bases is assumed to be invariant to population ageing. This seems to be an acceptable assumption given that, in theory, this relationship is determined by the tax structure of a country[53] and that the main drivers of tax buoyancy/elasticity are (depending on the type of tax): trade openness, population density, civil liberties, political rights, elements of tax policy, tax rate structure and importance of some industries (Ahmed & Mohammed, 2010; Bruce et al., 2006; Dudine & Jalles, 2017; Sarwar & Ashraf, 2016).[54]

5.2. Main results

89. The application of equation 3 generates the results shown in Figure 20 (baseline scenario). A first observation regards the fact that the results are overwhelmingly positive – only for Greece's general government the results are negative. The average revenue growth for the general government and central government was 34% (26% on a per capita basis) while for SNGs it was 44% (36% on a per capita basis). This difference was expected given the higher buoyancy for SNGs and small reliance on tax revenues dependent on labour income.

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[51] Extreme buoyancies (below 0.3 or above 2.5) were converted to the value closest to unity within the buoyancy coefficient's confidence interval. This occurred only for the revenue buoyancy of SNGs from Denmark, Ireland, Hungary and Norway. For Japan, a buoyancy of unity was defined due to the fact that the country has a relatively small number of observations (less than 15) and, thus, estimating buoyancy coefficients can be tenuous.

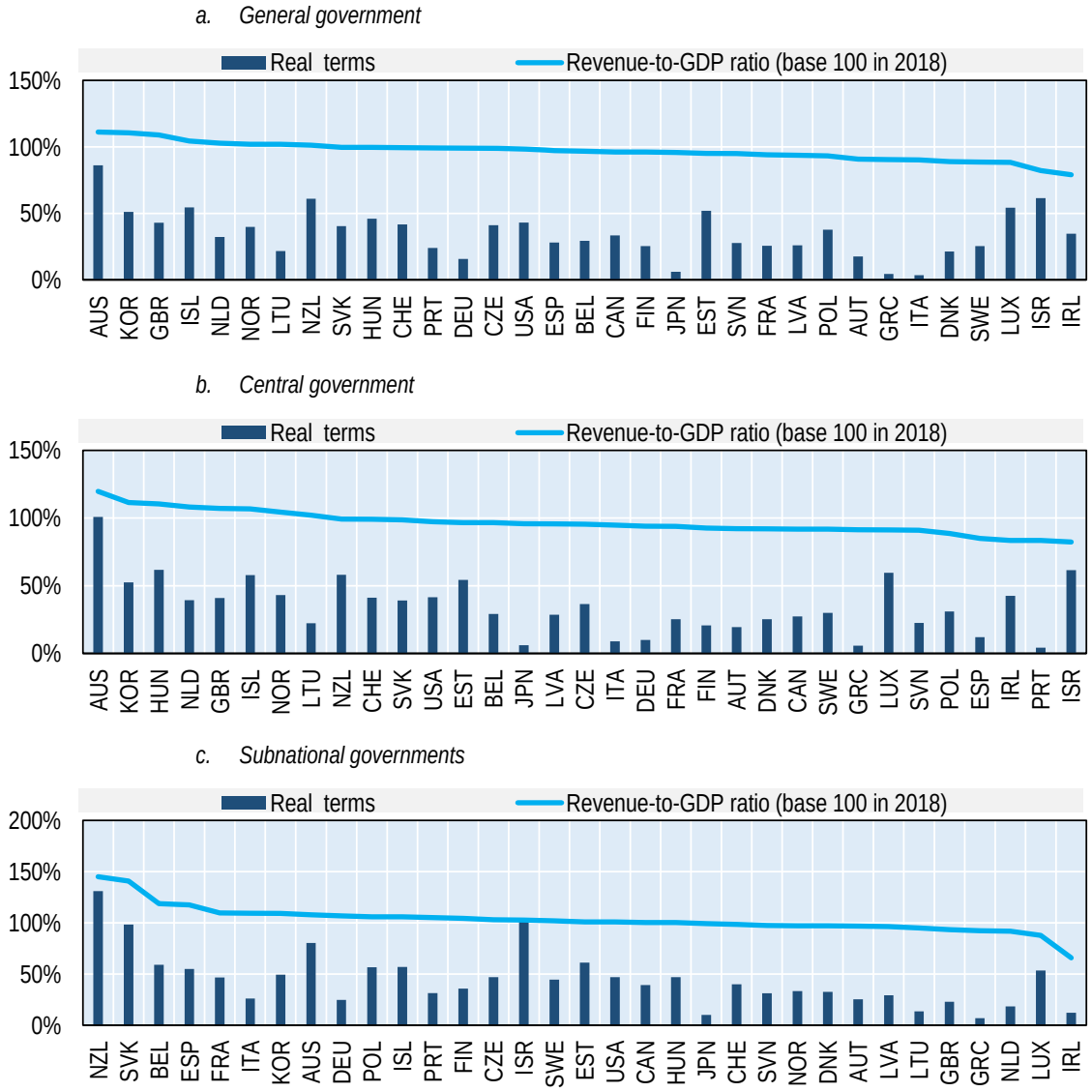
[52] Effects are compounded throughout the forecasting period.

[53] It is possible to estimate different tax elasticities for each age group, but for that purpose, specific tax structure data are needed, which are not available with the required level of detail in a comprehensive and harmonised manner across OECD countries.

[54] In addition, in order to test this assumption further, we regressed the share of population over 65 years old onto the buoyancy coefficients in two panel regression settings (with country fixed effects, and country and time fixed effects). In both regressions, the coefficient of the share of population over 65 years old was statistically insignificant (p-values of 0.96 and 0.25, respectively.

90. It is worth noting that among the countries with the lowest government revenue growth there are those with an older population (*e.g.,* Germany, Greece, Italy, Japan, Portugal, among others). In contrast, countries with a younger population (*e.g.,* Australia, Iceland, Israel, Luxembourg, New Zealand, among others) tend to be among those with the highest increase in government revenues. Countries with the highest revenue buoyancy also tended to be in the top half in terms of forecasted revenue growth (*e.g.,* Australia, Korea, Norway, Slovak Republic and the United Kingdom) while countries with the lowest revenue buoyancy tended to be in the group with the lowest forecasted revenue growth (*e.g.,* Denmark, Greece, Italy and Lithuania).

Figure 20. Government revenue forecasts in 2040 considering population ageing and buoyancy effects



Note 1: Ordered by general government's values. GG, CG and SNG refers to general government, central government combined with social security funds and subnational government, respectively. Values for all levels of government were computed separately and, thus, are not the weighted average of one another.
Note 2: Values from the first scenario, which is the one that the estimated buoyancy is used throughout the whole forecasting period.
Source: Authors' elaboration based on NTA UN, NTA EU. OECD population and GDP projections, OECD Revenue Statistics and SNA.

91. Figure 21 breaks down the government revenue forecast, shown in Figure 20, into two effects: the revenue buoyancy effect (including population growth) and change in the structure of population. In no combination of country and level of government was the buoyancy effect negative, which was expected given that the GDP growth rate is expected to be positive.[55] The buoyancy effect varied from 6% to 87% at the level of general government, 7% to 102% for central governments and 7% to 130% for subnational governments, respectively (in real terms). The average buoyancy effect was 39% for general government and also central governments, and 46% for SNGs.

92. In contrast, the changes in the structure of the population are, in most cases, expected to cause a reduction in government revenues. At the central and general government level, age structure effects are only positive for New Zealand (a relatively young country) and can be up to negative 8% (Slovenia's central government and Czech Republic's general government). On average, as a result of changes in the structure of the population, government revenues are expected to decrease through to 2040 by 3.9%, 3.8% and 1.1% at the general, central and subnational level of government, respectively.

Figure 21. Expected impact from population ageing and revenue buoyancy on government revenues (real growth rates)

Note 1: Age structure effect is the same variable as population ageing effect (per capita) from Figure 19, but the sample of this figure is smaller as it only covers countries for which data on government revenues and on GDP forecasts were available.
Note 2: Values from the first scenario, which is the one that the estimated buoyancy is used throughout the whole forecasting period.
Source: Authors' elaboration based on NTA UN, NTA EU. OECD population and GDP projections, OECD Revenue Statistics and SNA.

[55] See Guillemette & Turner (2021) for details on GDP per capita growth and OECD population projections for the expected population growth.

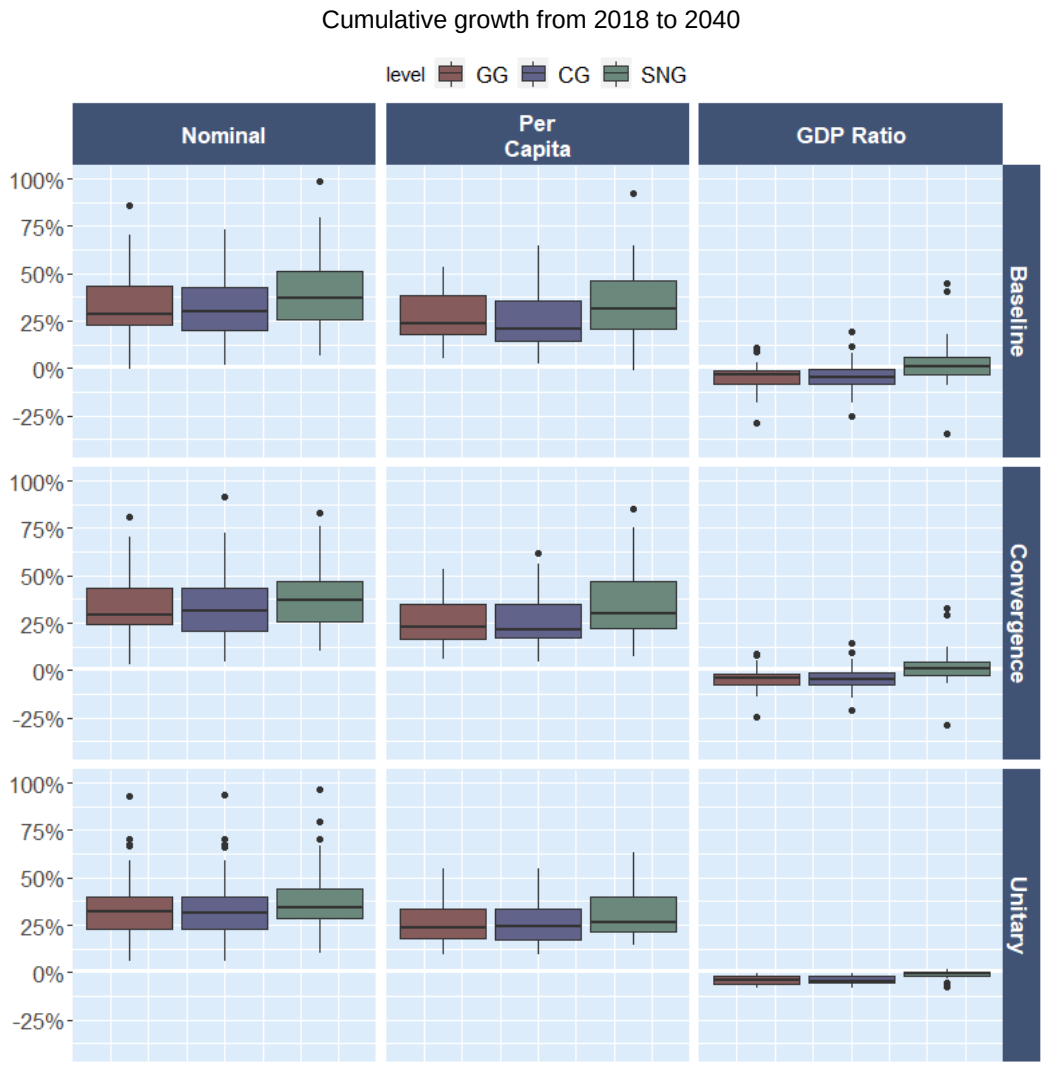
93. Finally, Figure 22 compares forecasted government revenue growth with population growth and expected GDP growth across the three scenarios. As many OECD countries are expecting an increase in population, the per capita growth in government's revenues was slightly smaller than its growth in real values, in all three scenarios.

94. When comparing the forecasted growth rates for government revenues with GDP growth, the outlook is not positive. As the mean buoyancy is 0.99, 0.97 and 1.09 for the general government, the central government and SNGs, respectively, the buoyancy effect alone tends to be only positive for the latter group. In addition, as explored by Figure 17, the effects from changes in the age structure are, by-and-large, negative. Thus, in most combinations of countries and levels of government, revenues are expected to decrease as a proportion of GDP.

95. More precisely, at the general level of government, the revenue-to-GDP ratio is expected to decrease by 4.29%, 4.24% and 3.94% in the baseline, convergence and unitary scenarios. At the central level of government, the revenue-to-GDP ratio is expected to decrease by 4.37%, 4.28% and 3.84% in the baseline, convergence and unitary scenarios. At the subnational level of government, the revenue-to-GDP ratio is expected to increase by 3.06%, 1.87% and decrease by 1.07% in the baseline, convergence and unitary scenario.

96. Two interesting conclusions can be drawn from these numbers. First, regardless of the scenario used to produce the buoyancy coefficients, general and central government revenues are by and large expected to decrease as a proportion of GDP as a result of population ageing in the long run. Second, subnational governments, as a result of the fact that their tax mix tends to be more resilient to ageing, tend to enjoy an increase in the revenue-to-GDP ratio in the case that past buoyancy is maintained in the future, or to be less negatively impact by population ageing in the case that buoyancy is unity. Box 3 compares these results with the results of a study on the impact of population ageing on Austria's government revenues.

Figure 22. Comparison of government revenues growth across the three scenarios



Note 1: Baseline scenario refers to the use of the estimated buoyancy throughout the whole forecasting period; the convergence scenario refers to the scenario in which buoyancy coefficients converge linearly to one in 2060; and the unitary scenario just assume that buoyancies are unitary.
Note 2: Nominal values are inflation adjusted.
Source: Authors' elaboration based on NTA UN, NTA EU. OECD population and GDP projections, OECD Revenue Statistics and SNA.

Box 3. Impact of population ageing in Austria

In an example of a related analysis using tax microdata, Prammer (2019) estimated the impact of population ageing on Austria's government revenues. The model consisted of age profiles and tax elasticities calculated for each age group. Despite the differences in the methods employed, the conclusions are similar to the present analysis.

First, Prammer (2019) found that ageing puts a strain on PIT and SSC revenues due to an increase in the number of retired individuals that would lead to a reduction of about 10% of PIT and SSC revenues on per capita terms. Applying our population ageing model to 2060 for Austria's general government, we found a reduction of 15% in PIT and SSCs, also per capita.

Second, when the author considers effects related to increases in GDP per capita, population size and tax elasticities, tax revenues will actually increase through to 2060. The same happens in our model when incorporating the effects from revenue buoyancy and the growth in potential GDP per capita.

Lastly, he found that the strongest mitigating factor was having a growing economy. This same conclusion is drawn in the present study, as a substantial portion of the growth in government revenues can be attributed to the expected growth in potential GDP per capita.

5.3. Policy discussion

97. This paper has produced findings that shed light on the impact of population ageing across countries and levels of government considering their tax mixes, revenue buoyancy, population projection and age profiles. When considering all of these factors, the average revenue growth for general government and central government is 34% (26% on a per capita basis) while for SNGs it is 44% (36% on a per capita basis). Nevertheless, as a result of population ageing, government revenues are expected to increase less than GDP in most combinations of countries and levels of government.

98. There are two caveats, however. First, this outcome depends on having GDP per capita grow at its full potential, which translates into increases in government revenues in line with the relationship previously observed between tax revenues and GDP. Second, as with any long-term forecasts, there are substantial uncertainties with regard to the parameters and inputs used in the forecasts, such as those related to demographic forecasting, GDP forecasting and buoyancy coefficients. Despite these uncertainties, it is likely that structural reforms targeted at increasing government revenues will be necessary to fund the costs of population ageing.

99. More specifically, pensions, long-term care and health care expenditures are expected to grow in the long term as a result of population ageing (Colin & Brys, 2020). Thus, even if GDP per capita and population growth might partially offset decreases in revenues from changes in the structure of the population due to population ageing, these effects might not be enough to fund higher spending needs. In addition, although changes in the structure of the population can lead to increases in revenues for some countries – for instance, those that are expected to experience an increase of the population in the 40–54 age group – the population will continue to age, and the negative impact of population ageing will likely increase over the longer term.[56]

[56] Although not explicitly covered in this paper, when equation 3 is applied to a longer time horizon, the negative impact from population ageing grows significantly.

100. Reforms to make revenues more robust to population ageing are likely to be necessary. Countries have many options to make their government's revenue mix more resilient to population ageing. In principle, this could be pursued through at least two channels: 1) adoption of more growth-friendly taxes, so output increases, boosting revenue collection for multiple taxes, and 2) adoption of reforms so that tax revenues are less affected by population ageing.

101. The adoption of more growth-friendly taxes can be particularly impactful as output growth is directly related to the buoyancy effect, whose magnitude is significantly higher than that of the ageing structure effect. Broader tax bases tend to reduce distortions in resource allocation and, thus, increase output growth. Therefore, all types of taxes can become more efficient by broadening their tax base and reducing tax exemptions. Boosting the reliance on property taxes can also improve output growth, as property taxes are considered a growth-friendly yet underused tax (OECD, 2021).

102. Another option is to adopt tax reforms with the purpose of making tax revenues more resilient to population ageing. GST/VAT revenues are largely invariant to population ageing while having an average buoyancy, meaning that they are more resilient to population ageing than most taxes. In countries where consumption is not already highly taxed, GST/VAT rates could be increased to boost resilience to population ageing. In countries where consumption is already relatively highly taxed, there might be specific goods and services that are undertaxed and targeted tax rate increases (e.g. such as removing reduced or special rates) could be an option.

103. PIT, SSCs and payroll taxes tend to be impacted the most by population ageing, as their tax bases are linked to labour income. While the revenue share of these taxes is expected to decline structurally over time, these taxes will remain important as the key drivers of progressivity in most tax systems. Against this backdrop, the case for maintaining existing effective tax rates is strong. Policy decisions to reduce effective tax rates on labour incomes (especially the PIT) could further increase income inequality (Cournède et al., 2018). Nevertheless, policies that change the age profile of labour income or increase the number of people in age groups that tend to earn more labour income can also make PIT, SSCs and payroll tax revenues more robust to population ageing. This can be done by raising labour force participation by, for instance, encouraging women, the elderly and/or immigrants to join/stay in the labour force. Another option could be to impose PIT and SSCs (*e.g.,* health SSCs) on pensions and, thus, minimise the decrease in tax revenues that will arise when people retire (for more details see OECD, 2021). An increase in productivity and, thus, wages could also increase tax revenues generated from labour income. Lastly, increasing the reliance on taxes on capital income at the personal level (classified under PIT) could also be particularly useful as these taxes can reduce inequality and are resilient to population ageing.

104. This paper finds that CIT[57] is the tax type whose buoyancy tends to be considerably higher than other types of taxes (on average), which means that it is relatively resilient to population ageing (*i.e.,* CIT revenues do not tend to decrease with population ageing, like taxes on labour income that are affected by the reduction in the labour force). Nevertheless, CIT can be a distortionary tax and, thus, an increased reliance on CIT could have negative effects on growth (Cournède et al., 2018). While this paper finds that CIT improves the resilience of tax systems to population ageing, governments will need to weigh these benefits against any of the CIT distortionary effects.

105. With regard to the political economy of these reforms, it is important that the tax burden to fund the health care system not be skewed towards certain age groups. This is particularly relevant when the group that bears the highest tax burden – workers – is different from the group that benefits the most from the welfare state – pensioners. This situation can potentially create intergenerational tensions (OECD, 2015). Therefore, as the working population shrinks, taxing them even more to compensate for the

[57] Note that the concept of CIT used here does not include capital income taxed at the personal level due to data aggregation issues.

reduction in tax revenues could: 1) create distortions in the labour market and 2) create intergenerational issues that could lead to less support for the welfare state. Therefore, a greater reliance on taxes on capital, property and pension income could boost the resilience of the tax system to population ageing and, at the same time, minimise social tensions that could undermine support for the maintenance of an effective social safety net.

106. Another issue related to population ageing is that its fiscal impact is likely asymmetric across regions. Regional disparities in tax mixes, economic base and demographic changes could exacerbate challenges across SNGs within a country. Felix & Watkins (2013) estimated population-ageing effects on US states' revenues and they found a substantial dispersion – depending on demographic changes, tax policy and tax mixes, these effects vary from a decrease of 35% to an increase of 50% in their income taxes. In the same vein, Kluge & Vogt (2020) estimated that the impact of population ageing on Germany's state revenues in 2050 could vary up to 29% depending on the state. Daniele et al. (2020) suggests that population ageing might affect urban and rural areas differently. Thus, the challenges posed by population ageing are expected to vary widely across regions and reforms to fiscal federalism might be necessary to cope with these differential impacts, as SNGs might have limited autonomy to solve the issue themselves.

107. This paper also shows that the impact of population ageing on government revenues will likely vary across levels of government. SNGs' tax mixes tend to be more robust to population ageing as they rely substantially more on recurrent taxes on immovable property and older people tend to have more property revenues than younger people. Nonetheless, it is worth noting that SNGs face other challenges. First, they often lack revenue autonomy (Dougherty et al., 2019) and, thus, in the event that spending needs grow as a result of population ageing (and they are expected to increase), they could face barriers to increasing their revenues proportionally. Second, formulas for defining the distribution of revenues from grants and tax sharing arrangements do not systematically account for expenditure pressures from demographic changes (Colin & Brys, 2020), and therefore intergovernmental transfers are not expected to increase SNGs' revenues in line with fiscal pressures from population ageing. As a result, reforms to intergovernmental fiscal relations are likely to be needed to overcome the fiscal challenges arising from population ageing.

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Annex A: Difference in tax revenues as a share of GDP between 1995 and 2018

The revenues from different tax types as a share of GDP have varied little over the period between 1995 and 2018. The last row of Table A1 shows that for all tax types, for the majority of countries the share of each type of tax revenue did not increase or decrease more than one percentage point of GDP. Therefore, by and large a country's tax composition tends to remain relatively constant over time.

Table A1. Difference in tax revenues as a share of GDP between 1995 and 2018

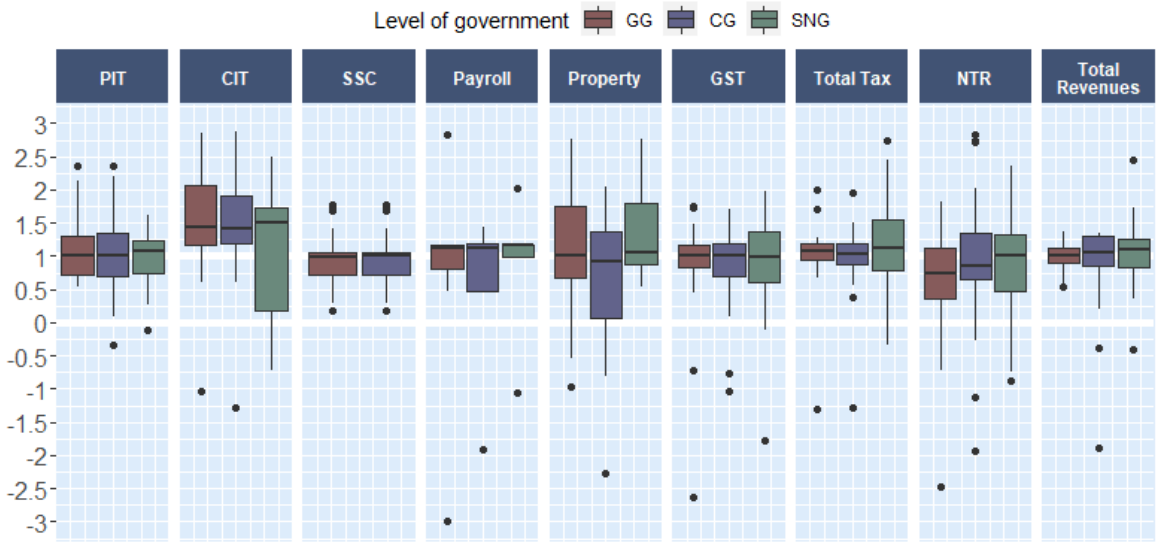
	PIT	CIT	SSCs	Payroll	Property	GST/VAT	Other
CZE	-0.10%	-0.60%	1.10%	0.00%	0.00%	0.20%	0.00%
AUT	0.30%	1.30%	0.00%	-0.10%	-0.10%	-0.30%	-0.10%
DEU	0.50%	1.10%	0.40%	0.00%	0.10%	0.20%	0.00%
MEX	-0.80%	0.60%	0.00%	0.20%	0.10%	0.50%	0.10%
CHE	0.50%	1.80%	-0.20%	0.00%	0.00%	0.40%	0.10%
USA	0.40%	-1.50%	-0.60%	0.00%	0.00%	-0.50%	0.00%
AUS	0.30%	1.30%	0.00%	-0.50%	0.20%	-0.90%	0.00%
NLD	0.80%	0.50%	-0.80%	0.00%	0.00%	1.10%	0.00%
ESP	0.20%	0.80%	0.50%	0.00%	0.70%	1.10%	0.00%
CHL	0.60%	2.30%	0.30%	0.00%	-0.10%	-0.20%	-0.10%
GBR	0.50%	0.30%	1.10%	0.10%	1.20%	0.40%	0.00%
DNK	-2.30%	0.50%	0.00%	0.10%	0.20%	-0.60%	0.00%
CAN	-0.90%	1.00%	-0.20%	-0.10%	0.20%	-1.00%	-0.40%
SVN	-0.50%	1.40%	-1.90%	-0.10%	0.10%	-0.80%	0.00%
LUX	1.60%	0.00%	1.40%	0.00%	1.40%	0.50%	0.00%
FIN	-1.60%	0.30%	-1.90%	0.00%	0.40%	0.70%	-0.10%
EST	-2.70%	-0.40%	-0.40%	0.00%	-0.10%	1.50%	0.00%
SVK	-0.10%	-2.90%	0.10%	0.00%	-0.10%	-2.10%	0.00%
PRT	1.10%	1.10%	1.70%	0.00%	0.50%	1.00%	0.20%
POL	-2.90%	-0.60%	2.00%	0.00%	0.00%	0.10%	0.00%
NZL	-4.20%	0.90%	0.00%	0.00%	0.00%	0.60%	0.00%
ISR	-2.80%	0.60%	0.30%	-0.50%	-0.30%	-1.60%	0.00%
HUN	-1.20%	-0.50%	-2.70%	0.80%	0.50%	0.20%	-0.40%
LVA	1.10%	-0.60%	-1.90%	0.00%	-0.10%	2.80%	0.00%
ITA	0.90%	-1.50%	0.90%	-0.10%	0.40%	1.50%	1.40%
BEL	-2.10%	2.00%	-0.80%	0.00%	1.80%	0.20%	0.00%
NOR	-0.40%	2.80%	0.70%	0.10%	0.10%	-3.10%	0.00%
JPN	0.30%	0.00%	4.20%	0.00%	-0.60%	2.20%	0.00%
COL	0.80%	1.70%	-1.80%	-0.30%	1.10%	1.30%	0.40%
LTU	-2.20%	-0.50%	5.50%	0.00%	0.00%	-0.20%	0.00%
KOR	1.50%	2.00%	4.50%	0.00%	0.50%	-0.60%	0.10%
FRA	4.60%	0.00%	-2.00%	0.50%	1.20%	0.40%	-1.10%
SWE	-2.20%	0.20%	-2.90%	4.10%	-0.30%	-0.30%	0.00%
IRL	-3.10%	0.50%	-0.40%	-0.20%	-0.10%	-5.80%	0.00%
GRC	3.10%	-0.10%	2.60%	0.00%	1.30%	3.60%	0.00%
ISL	6.20%	1.70%	1.00%	0.30%	-0.80%	-2.50%	0.60%
TUR	0.20%	1.00%	5.20%	0.00%	0.50%	3.60%	-2.80%
Share<1%	**51%**	**54%**	**51%**	**97%**	**84%**	**57%**	**92%**

Source: Authors' elaboration based on OECD Revenue Statistics.

Note: Ordered by the sum of the absolute value of the variation of all seven categories. The darker blue cells are the higher the increase in the share of the respective tax revenues as a percentage of GDP and the darker the red cells are the higher the decrease in the same share. Last row refers to the percentage of countries for which the share of the respective tax revenue varied less than 1% of GDP. For Mexico the base year is 2001 instead of 1995.

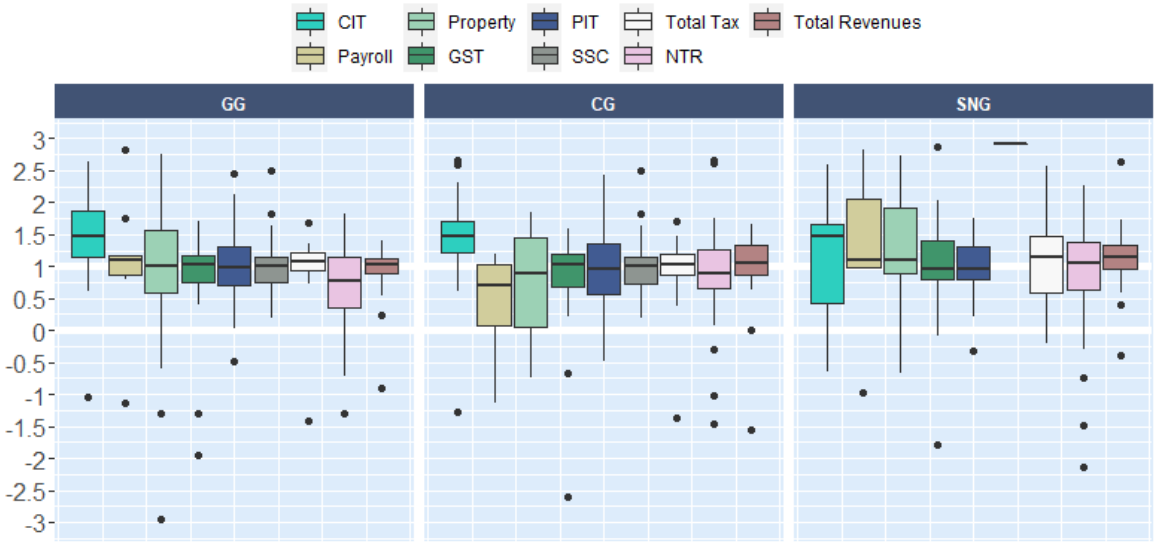
Annex B: Robustness checks

Figure B1. Boxplot of the long-run buoyancy coefficient using a robust regression instead of OLS



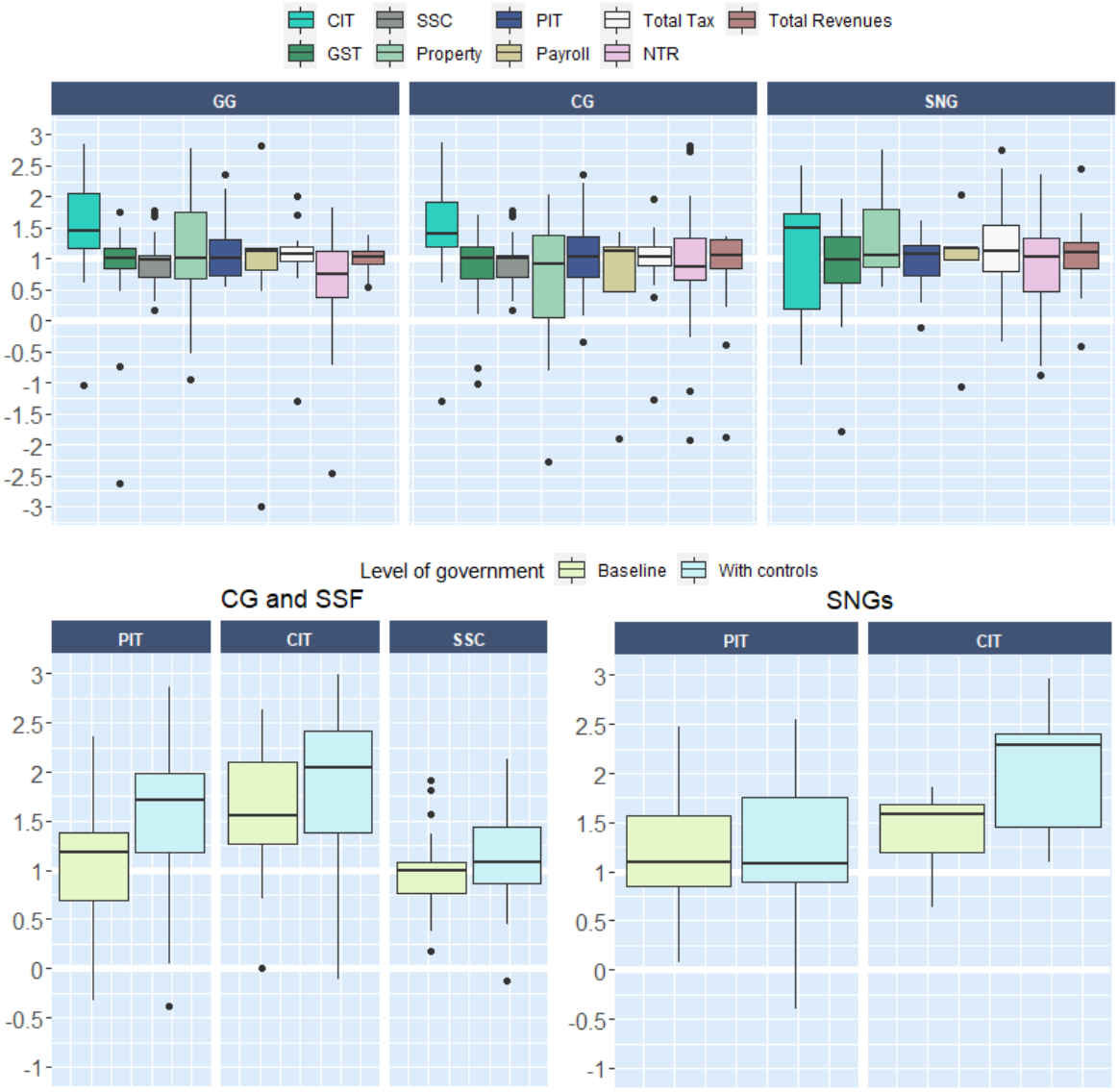
Note: The same ECM from the equation 2 was used but coefficients were estimated using a robust regression instead of an OLS. More precisely, a MM-type regression estimator is used, as described in Yohai (1987) and Koller & Stahel (2011), which are especially good for small samples. Robust estimators can be almost as efficient as least squares when the error distribution is normal, and much more efficient when the errors are heavy tailed (Fox, 2015).
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

Figure B2. Boxplot of the long-run buoyancy coefficient using a robust regression instead of an OLS



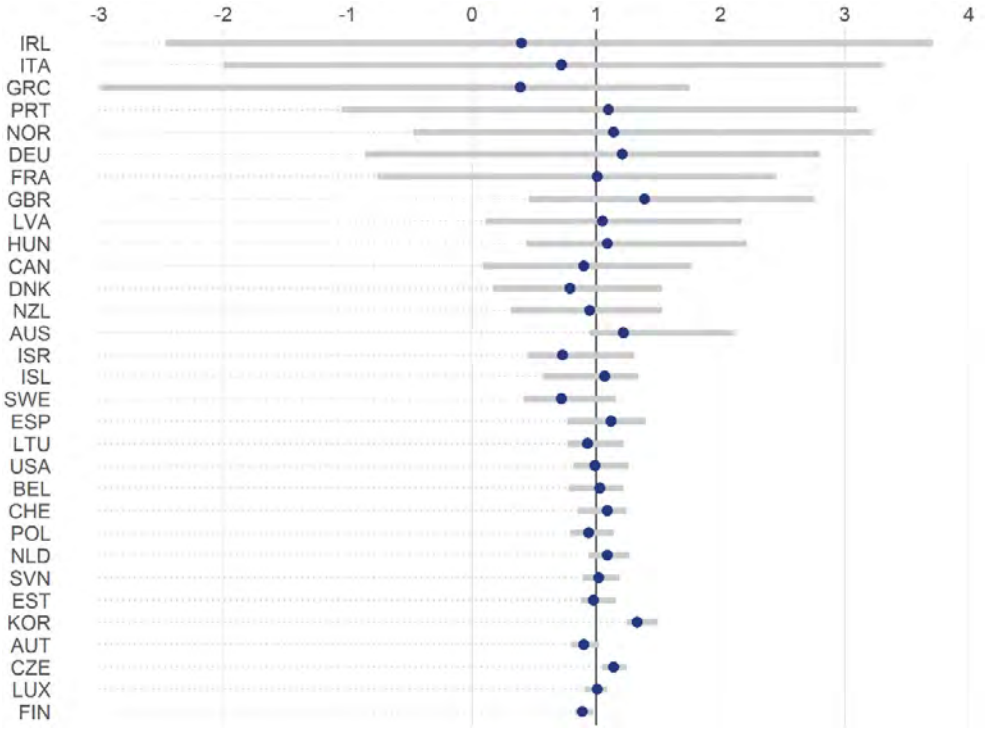
Note: Same as Figure B1.
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

Figure B3. Comparing the baseline model with a model that controls for PIT, CIT and SSCs for top tax rates



Note: As data on tax rates are available only since 2000, these estimates considered only the period 2000-2018 instead of 1990-2018. For SSCs two controls were used: the top tax rate for employers and employees. For PIT and CIT only the top tax rate for the respective level of government was used as control.
Source: Authors' elaboration based on OECD Revenue Statistics for both tax revenues and tax rates.

Figure B4. The 95% confidence interval for the buoyancy coefficient for general governments' total revenues



Note: Blue circles refer to the long-run buoyancy while the grey line to the 95% confidence interval. As the long-run buoyancy is estimated by taking the ratio between two coefficients (for details see section 3.2), bootstrapping was used to estimate the 95% confidence interval (1000 simulated samples). Values are not capped.
Source: Authors' elaboration based on OECD Revenue Statistics and System of National Accounts.

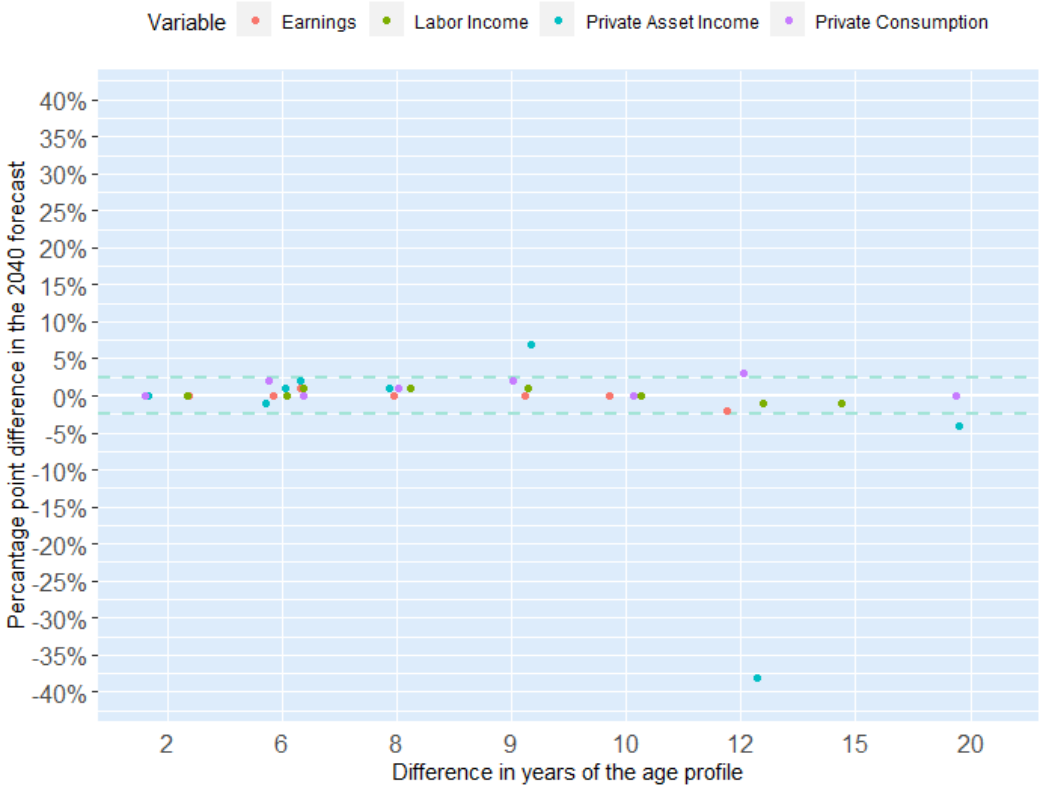
Annex C: Differences in the age profiles over time

The National Transfer Accounts (NTA) from the United Nations[58] have data time series data time for some OECD countries. These data can be used to test whether over time changes in the age profiles can affect the estimations of the tax base in the future. In order to make this verification, we applied equation 2 to the countries for which there are data on age profiles for multiple years. We considered 2018 and 2040 as the base and the forecast year, respectively.

The results show that in 27 out of 31 cases (Figure C1) the differences in percentage points of the of population ageing's impact on tax bases in 2040 when using age profiles from different years are between -2.5% and 2.5% (dashed lines). In most cases (21 out of 31) these differences are between the -1% and +1% mark and they are still the minimum even for age profiles that are more than 10 years apart. Thus, it seems that over time changes in countries' age profile are not large enough to impact substantially our forecasts.

[58] In contrast, NTA from the European Union have data only for 2010.

Figure C1. Difference in percentage points of the of impact of population ageing on tax bases in 2040 when using age profiles from different years



Note: The y axis refers to the difference in percentage points between two forecasts and the X axis refers to the difference in years of the age profiles. The plot covers the following countries: Australia, Austria, Costa Rica, Finland, France, Korea, Slovenia and the United States (OECD countries for which there is data for multiple periods in NTA UN). Dashed lines refer to -2.5% and +2.5%. The outlier of -38% refers to Korea's private asset income.
Source: Authors based on NTA UN.

Annex D: Dealing with missing data in the NTA

Figure D1, below, summarises the data availability and the year of the age profile of the tax bases for OECD countries in both the NTA EU (in light blue) and NTA UN (in light blue). Most data come from the previous decade (only for Chile, Colombia, Japan, Mexico and Türkiye the age profile is from before 2010) and only for 6 out of 37 countries there are no age profile data (Switzerland, Iceland, Israel, Netherlands, Norway and New Zealand) and for 2 out of 37 countries the data are incomplete (Canada and Türkiye).

Figure D1. Data availability in NTA datasets

Country	Labour Income	Private Asset Income	Private Consumption
AUS	2010	2010	2010
AUT	2010	2010	2010
BEL	2010	2010	2010
CAN	2011	-	2011
CHE	-	-	-
CHL	1997	1997	1997
COL	2008	2008	2008
CZE	2010	2010	2010
DEU	2010	2010	2010
DNK	2010	2010	2010
ESP	2010	2010	2010
EST	2010	2010	2010
FIN	2010	2010	2010
FRA	2010	2010	2010
GBR	2010	2010	2010
GRC	2010	2010	2010
HUN	2010	2010	2010
IRL	2010	2010	2010
ISL	-	-	-
ISR	-	-	-
ITA	2010	2010	2010
JPN	2004	2004	2004
KOR	2012	2012	2012
LTU	2010	2010	2010
LUX	2010	2010	2010
LVA	2010	2010	2010
MEX	2004	2004	2004
NLD	-	-	-
NOR	-	-	-
NZL	-	-	-
POL	2010	2010	2010
PRT	2010	2010	2010
SVK	2010	2010	2010
SVN	2010	2010	2010
SWE	2010	2010	2010
TUR	2006	-	2006
USA	2011	2011	2011

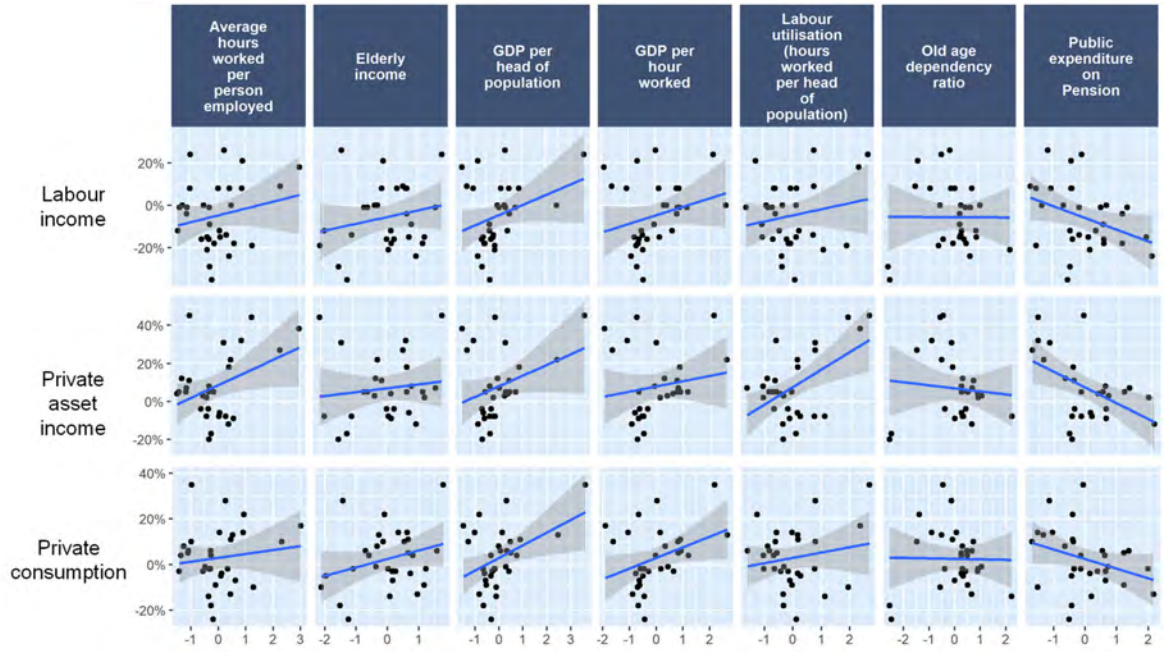
Note: Cell values refer to the year of the age profile. Light blue and green cells indicate that the data come from NTA EU and NTA UN, respectively. Blank cells refer to missing data.
Source: Authors based on NTA UN and NTA EU

In order to deal with missing data, age profiles of similar countries were averaged. More specifically, we clustered the data into four groups based on three variables that are related to the age profiles and within each cluster the scaled[59] value of the age profiles was averaged. The empirical processes of variable selection and clustering are further explained below.

For selecting variables that are related to the age profile, we applied equation 2 to all countries with data available and tried to predict the forecasts' results in 2040 by using seven variables. These variables are elderly income as a percentage of average income, old age dependency ratio, public expenditure on pension, GDP per head of population, GDP per hour worked, average hours worked per person employed and labour utilisation (hours worked per head of population). These seven variables were selected because they, intuitively, seem to be related to the age profiles of labour income, private asset income and private consumption. For instance, the higher the productivity (GDP per hour worked), everything else held constant, the higher the incentives for people to work but the higher the public expenditure on pension the lower the incentives for the elderly to work. Similar rationale applies to other variables.

For illustrative purposes, Figure D2 shows how these variables perform individually when trying to predict the results from equation 2 as independent variables of a simple OLS regression (all independent variables are normalised):

Figure D2. Predicting the result of the forecast of the impact of populating ageing on the respective tax base in 2040



Note: The Y axis refers to the impact of population ageing on the tax bases – so, for instance, +20% means that the country is expected to enjoy an increase of 20% with regard to the respective tax base due to population ageing. The X axis refers to the normalised values of the independent variables.
Source: Authors based on NTA and OECD Statistics data.

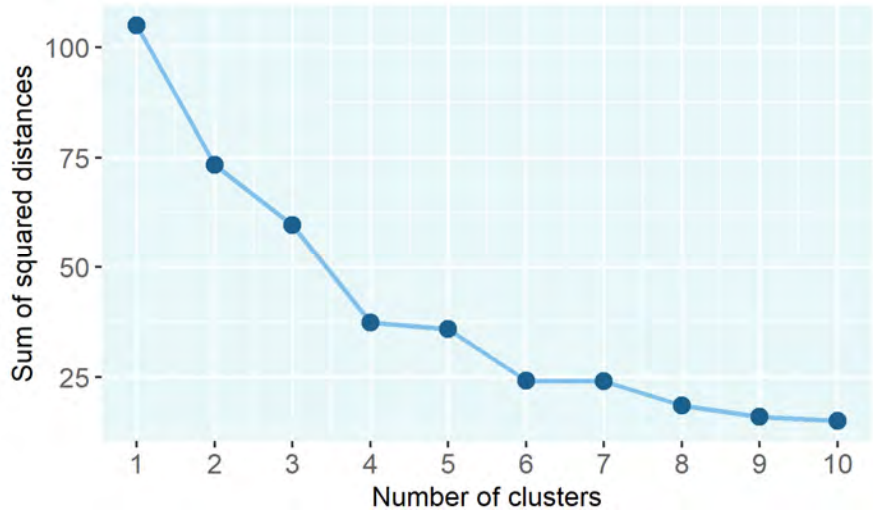
[59] The per capita values of the age profiles were divided by the average of all ages so all variables are a dimensionless quantity and, thus, comparable (without doing this scaling activity different currencies would bias the average).

As a rule of thumb, one should have at least 10 observations for each independent variable. Therefore, as there are 29 countries with data available for all three tax bases and 31 countries with data available for at least two tax bases, we selected only the best three variables, in terms of predictive power, out of the seven aforementioned variables. For that purpose, we regressed the impact of population ageing on all three tax bases in 2040 (dependent variable) onto all possible combinations up to three of these seven variables (independent variables). We then selected the combination with the lowest Akaike Information Criterion (AIC).

For all three tax bases, a combination containing three variables was selected, and in all of them public expenditure on pension and elderly income as a percentage of average income were in the best combination. For both labour income and private consumption, the 3rd variable in the combination was GDP per hour worked while for public asset income the 3rd variable was GDP per head of population (while the very close second-best combination for public asset income contained GDP per hour worked instead of GDP per head of population). Therefore, the three variables selected to cluster countries were public expenditure on pension, elderly income as a percentage of average income and GDP per hour worked.

The last step was to cluster countries based on these three variables. For that purpose, the k-means clustering method was employed.[60] In order to select the number of clusters, the elbow heuristic method was employed.[61] Figure D3, below, suggest that both four and six clusters are good picks. We chose four due to the fact we have only 36 observations and, thus, we minimise the changes of having a group with too few countries.[62]

Figure D3. Elbow method: Sum of square distances VS number of clusters



Source: Authors.

[60] K-means clustering method separates a dataset into "n" clusters in which each observation belongs to the cluster with the nearest mean in a manner that minimizes within-cluster variances – that is squared Euclidean distances (James et al., 2013).

[61] The method consists of plotting the explained variation as a function of the number of clusters, and eyeballing the plot, looking for a point at which the proportion of variance explained by increasing the number of clusters subsequent drops off (see James et al., 2013).

[62] Clustering only depends on the data availability of the independent variables and, thus, the countries with missing data from the NTA are in the sample.

Finally, Table D1 reveals the members of each cluster, while Figure D4 shows boxplots with the three independent variables aggregated by clusters. The following summarises the results (all relative to OECD countries):

- Cluster 1: consists of countries with high relative elderly income, low GDP per hour worked and low public expenditure on pension.
- Cluster 2: consists of countries with average relative elderly income, highest GDP per hour worked and average public expenditure on pensions.
- Cluster 3: consists of countries with the highest relative elderly income, average GDP per hour worked (with some outlies such as the USA and Luxembourg), and highest public expenditure on pension.
- Cluster 4: consists of countries with the lowest relative elderly income, relatively low GDP per hour worked and relatively low public expenditure on pension.

Table D1. Clustering results

1	2	3	4
CAN	BEL	AUT	AUS
CHL	CHE	ESP	CZE
HUN	DEU	FRA	EST
ISL	DNK	GRC	KOR
ISR	FIN	ITA	LTU
JPN	GBR	POL	LVA
MEX	IRL	PRT	
NZL	LUX	SVN	
SVK	NLD		
TUR	NOR		
	SWE		
	USA		

Source: Authors.

Figure D4. Relation between independent variables and clusters

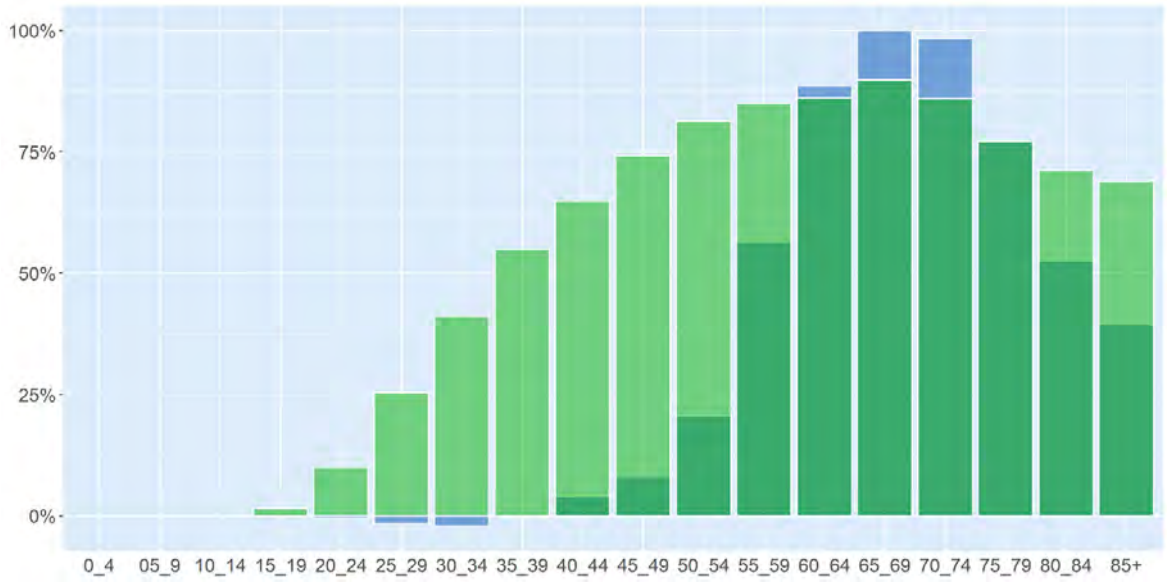
Source: Authors.

Annex E: Outlier analysis: Korea's private asset income age profile in comparison to the OECD average

Figure E1 compares Korea's private asset income age profile with the "average" age profile of OECD countries. The average profile suggests that in OECD countries it is common for people to have private asset income in their 20s, which grows gradually until their 70s. As a result, the private asset income of people in their 40s and 50s is only a bit smaller than those of people above their 60s. In Korea, though, there is a huge disparity between these values as people start to have substantial private asset income only after their 50s and this income grows steadily until its peak in their 60s and early 70s.

This discrepancy explains the high positive population ageing effect for Korea's aggregate private asset income.

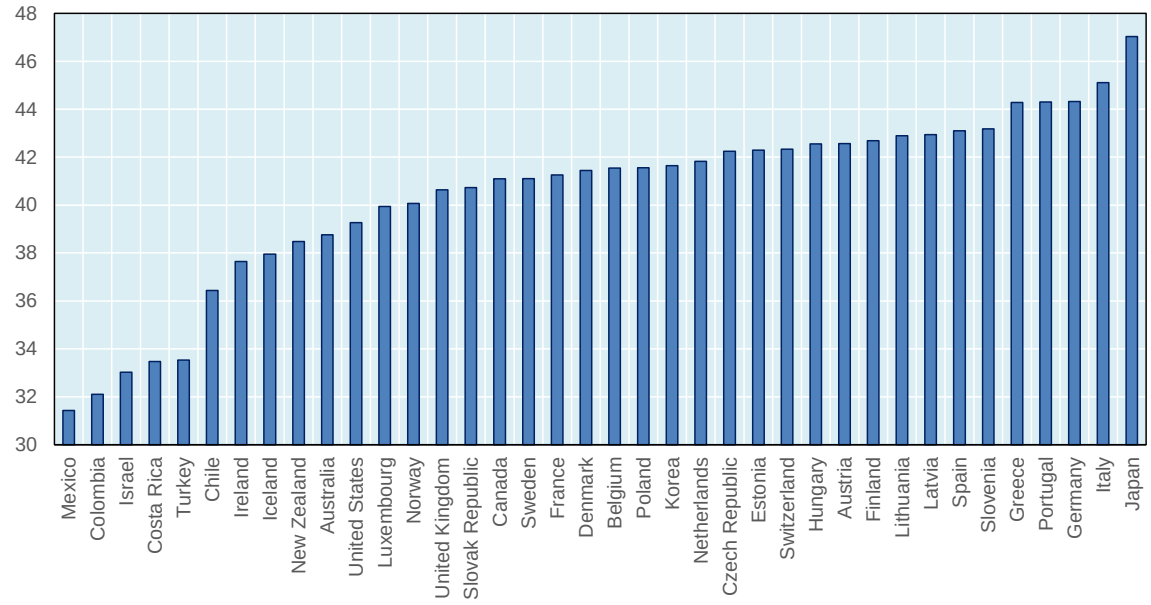
Figure E1. Korea's age profile for private asset income (blue) in comparison to the OECD average (light green) – overlaps are in dark green (values as a percentage of the private asset income of the top earning group)



Source: Authors based on NTA UN and NTA EU.

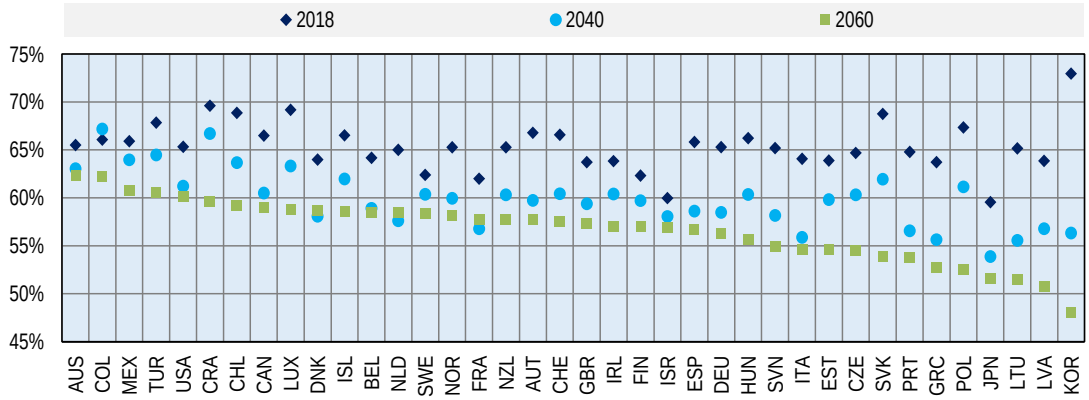
Annex F: Demographic data

Figure F1. Average age of the population as of 2018



Source: Authors based on OECD demography data.

Figure F2. Working-age population as a percentage of total population



Note: Working age population is defined as those aged 15 to 64.

Source: Author based on OECD Population Projections.

Appendix: Regression tables

Table AP1. Total Revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	2.96***	1.22.	-0.19	NA	2.77***	1.37	-0.11	0	1.02	1.15*	-0.56*	0
AUT	-0.09	0.9***	-0.91***	-0.06*	-0.11	0.95***	-0.68***	-0.05*	0.07	0.91	-0.22	-0.04
BEL	0.37	1.03.	-0.28.	-0.04*	0.22	1.02.	-0.5.	-0.05	-0.15	1.63	-0.14	-0.05
CAN	0.95*	0.9	-0.13	0.02	1.17.	0.78	-0.18	0.03	0.41	1.01	-0.14	0.01
CHE	0.72.	1.09.	-0.5.	0	1.77***	1.07***	-0.8***	0.03	0.08	1.03	-0.25	-0.01
CZE	1.23***	1.14***	-0.72***	0.01	0.96.	1.08*	-0.61*	-0.01	1.34	1.08*	-0.58*	-0.02
DEU	0.72***	1.21	-0.18	0	0.84***	0.93.	-0.49.	0.02	0.62.	1.51	-0.2	-0.03
DNK	0.73.	0.79	-0.46	-0.01	0.35	0.86	-0.43	-0.03	-0.37	-0.12	-0.04	0
ESP	2.41***	1.12***	-0.74***	0.04	2.12.	0.63*	-0.59*	0.08	0.6	1.68***	-0.95***	0
EST	0.19	0.98***	-0.62***	-0.06	0.24	1.01***	-0.58***	-0.06	0.43	1.02***	-0.72***	0
FIN	1.05***	0.89***	-0.52***	0.02	0.98***	0.74***	-0.48***	0.02	-0.02	1.18***	-0.14*	-0.01
FRA	0.8***	1.01	-0.07	0	1.04***	1.03.	-0.36.	-0.01	0.26	1.36	-0.19.	0.02
GBR	2.06***	1.39	-0.25	0.04	2.13***	1.34	-0.25	0.05	-0.52	0.75	-0.18	-0.01
GRC	0.6.	0.39	-0.15.	0.02	0.7.	0.46	-0.11	0.03	0.98	0.44	-0.72***	0.07
HUN	0.73	1.09.	-0.31.	0.03	0.67	1.36.	-0.29.	0.02	0.36	18.3	0	-0.11
IRL	0.06	0.4	-0.11	-0.12***	0.07	0.5	-0.13	-0.11***	0.77	-1.48	-0.11	0.07
ISL	2.38*	1.07***	-0.99***	0.04	2.23*	1.12***	-1.21***	0.06	1.66***	1.16.	-0.47.	0.01
ISR	1.48***	0.73	-0.31	0.04	1.43***	0.73	-0.32	0.05	0.77*	1.04	-0.07	-0.03
ITA	0.59	0.72	-0.27.	0.01	0.18	1.06	-0.15	0	0.07	1.71***	-0.5***	0.01
KOR	1.13***	1.33*	-0.46*	0.02	1.28***	1.37*	-0.44*	0.05	0.03	1.26***	-0.63***	-0.12.
LTU	0.92*	0.93.	-0.51*	0.03	1.26.	0.99.	-0.62.	0.07	-0.38	0.7	-0.41*	-0.13
LUX	0.82***	1.01*	-0.69*	0.01	0.74***	1.04***	-0.6***	0.02	0.38	0.78.	-0.55.	0.01
LVA	0.88***	1.05	-0.2	0	0.85.	1.09	-0.3	-0.01	0.66.	1.12***	-0.76***	0.07
MEX	-0.62	-0.91	-0.1	-0.22	0.03	-0.24	-0.1	-0.18	-1.52	0.79	-0.16	-0.15
NLD	1.65***	1.09***	-0.44*	0.03	1.25***	1.3.	-0.33.	0.01	-0.74	0.65***	-0.87***	-0.03
NOR	1.33.	1.14	-0.27	-0.02	1.39	1.2	-0.2	-0.05	1.53	-49.37	0	0.19*
NZL	1.09*	0.95.	-0.28	0	1.07.	0.9.	-0.33	-0.01	1.01.	1.81***	-0.12.	0.04
POL	1.71***	0.94*	-0.65*	NA	1.44.	0.8***	-0.75*	0	-0.27	1.2***	-1.03***	0
PRT	1.01.	1.1	-0.17	0.01	0.55	0.32	-0.13	0	0.5	1.23	-0.44*	0.01
SVK	0.6	1.22	-0.17	0	0.55	1.2	-0.12	0.01	1.88	2.01	-0.29	0.03
SVN	0.94***	1.02.	-0.47.	0.01	0.66*	0.85	-0.24	-0.01	0.14	1.05.	-0.34*	0
SWE	0.82*	0.72	-0.34	-0.01	1.04	0.8.	-0.58*	-0.01	0.33	1.13	-0.29	-0.01
USA	2.02***	0.99*	-0.38*	0	2.72*	0.99*	-0.36*	0	0.58*	1.02*	-0.33***	0

Table AP2. Total tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	2.47***	1.1	-0.18	NA	2.58***	1.19	-0.18	0	2.34.	0.78.	-0.32.	0
AUT	0.28	0.93*	-0.34*	-0.06.	0.55	0.89	-0.18	-0.04	-2.45	-0.61	-0.25	-0.15
BEL	0.85***	1.01	-0.28	-0.01	0.87.	0.8	-0.25	0	0.35	2.81	-0.28	-0.02
CAN	0.94.	0.87	-0.13	0.02	1.21*	0.72	-0.19	0.03	0.75	0.99	-0.18	0.01
CHE	0.8.	1.1	-0.2	-0.01	0.99	1.12	-0.26.	-0.02	0.61	1.12	-0.29	0
CHL	1.85***	1.17***	-0.57***	-0.08	2.03***	1.18***	-0.55***	-0.08	-0.12	1.04.	-0.37*	-0.01
COL	1.68***	1.23***	-0.39***	0.03	1.79***	1.19***	-0.39***	0.02	1.14***	1.48***	-0.73***	0.07
CZE	1.23***	1.06***	-0.43*	0	1.82***	1.04***	-0.93***	0.03	-7.33	1.29	-0.46***	-0.4
DEU	0.92*	1.11***	-0.57***	-0.01	0.8*	1.01***	-0.69***	-0.01	1.17*	1.4.	-0.34.	-0.03
DNK	0.92.	0.94	-0.37	-0.02	0.98	1.2.	-0.51.	-0.01	1.14	0.22	-0.24	0.01
ESP	2.21***	1.12***	-0.59***	0.02	2.27***	0.83***	-0.7***	0.01	3.17*	2.43*	-0.58*	0.09
EST	0.4.	0.96***	-0.42***	-0.05	0.4.	0.96***	-0.43***	-0.05	-	-	-	-
FIN	1.18***	0.87*	-0.47*	0.01	1.27***	0.84***	-0.6***	0.01	0.81.	0.93	-0.17	0.01
FRA	1.01*	1.08	-0.12	0	1.29***	1.04.	-0.34.	0	0.31	1.68	-0.29	0.01
GBR	1.75***	1.24.	-0.32.	0.01	1.81***	1.2.	-0.33.	0.01	-0.14	1.76***	-0.71***	-0.05
GRC	0.39	-2.44	-0.02	-0.02	0.38	-2.32	-0.02	-0.03	0.06	0.14	-0.09	-0.03
HUN	1.01***	0.97***	-0.34*	0.05.	1.08***	0.95***	-0.28*	0.05.	0.06	0.95	-0.16	-0.02
IRL	0.17	0.67	-0.1	-0.12***	0.19	0.67	-0.09	-0.12***	-0.38.	0.59	-0.14*	0.03
ISL	2.9***	1.23***	-0.98***	0.05	3.17***	1.14***	-1.01***	0.06	1.86***	1.46.	-0.38.	0.02
ISR	1.64***	0.85.	-0.38.	0.02	1.69***	0.83	-0.33	0.02	1.2***	0.77	-0.09	0.01
ITA	0.78	1.15.	-0.38***	0.02	0.09	0.45	-0.42.	0	7.53.	7.81	-0.33.	0.24
JPN	1.96***	3.51***	-0.12	0.01	2.08***	3.97***	-0.11	0.01	1.51***	1.89***	-0.28.	0.01
KOR	1.25***	1.3.	-0.43.	0	1.32***	1.32*	-0.55*	0.01	0.66	1.12.	-0.37.	-0.13
LTU	1.28***	0.97.	-0.38.	0.06	1.3***	0.97.	-0.39.	0.06	-	-	-	-
LUX	0.65.	1.11.	-0.38.	0	0.65.	1.14.	-0.43.	0	-	-	-	-
LVA	0.97***	1.2	-0.1	-0.01	0.85***	1.01	-0.28	-0.04	-	-	-	-
MEX	2.16***	2.18	-0.14	0.04	2.16***	2.1	-0.15	0.04	1.9	2.69	-0.09	0.03
NLD	1.18*	1.37	-0.07	0	1.19*	1.27	-0.09	0	0.86	1.3	-0.25	0.02
NOR	1.36***	1.11	-0.08	0.01	1.45*	1.25	-0.06	-0.01	1.59	0.4	-0.29	0.14
NZL	1.76***	0.9	-0.26	0.01	1.81***	0.87	-0.25	0.01	0.85	1.26***	-0.31***	0.03
POL	1.47*	0.9.	-0.44.	NA	1.24.	0.83.	-0.39.	0	3.16***	1.43***	-0.59***	0
PRT	1.43***	1.31	-0.23	0.01	1.44***	1.29	-0.28	0.01	1.47	2.11	-0.16	0
SVK	0.57.	3.26	-0.02	-0.04	0.54.	6.3	-0.01	-0.05	-	-	-	-
SVN	1***	0.98.	-0.5.	-0.01	0.97***	0.91.	-0.36.	-0.01	-	-	-	-
SWE	0.91*	0.86.	-0.27.	-0.03	1.22*	0.7.	-0.25*	-0.04	0.24	1.16***	-0.41***	0
TUR	1.31***	1.03	-0.13	0.06	1.41***	1.04	-0.13	0.07	0.95	1.19	-0.27.	0.03
USA	2.56***	0.96*	-0.35*	0.01	3.12***	0.93*	-0.33*	0	1.43***	1.02	-0.27	0.01

Table AP3. Non-tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	5.9	1.98***	-0.62***	NA	2.26	1.5***	-1.04***	0	0.22	1.38.	-0.44*	0
AUT	0.54	1.14*	-0.51*	0.09	0.15	1.22	-0.35.	0.09	-0.03	0.95.	-0.29.	-0.05
BEL	-1.24	1.54	-0.2	-0.05	-1.35	2.4*	-0.71***	-0.13	-0.17	1.31	-0.26	-0.05
CAN	0.48	1***	-0.85***	-0.04	-0.6	1.44.	-0.58***	-0.1	-0.02	0.98	-0.22	-0.01
CHE	-0.27	1.08***	-0.64***	-0.05	4.23.	0.92***	-0.92***	0.1	-0.24	1	-0.4*	-0.02
CZE	-0.14	1.65*	-0.67***	0	-20.75	4.57	-0.58*	-0.84	1.39	1.07*	-0.58*	-0.02
DEU	0.74	-0.11	-0.54***	0.03	1.5***	0.11	-0.5***	0.09***	0.12	1.32	-0.09	0
DNK	1.23	0.58	-0.17	0.07	-0.56	-0.28	-0.35	-0.03	-1.18.	2.14*	-0.18***	-0.03
ESP	-1.27	0.39*	-0.6***	0.01	-0.87	-0.7	-0.29.	0.22	-1.45.	1.31***	-1.18***	-0.07
EST	NA	NA	NA	NA	NA	NA	NA	NA	0.46	1.05***	-0.73***	0
FIN	0.42	1*	-0.33*	0.03	-0.21	0.33	-0.32***	0.01	-0.79.	1.41***	-0.15***	-0.03
FRA	-0.67	1.31*	-0.52***	-0.05	-0.76	1.03***	-0.72***	-0.08	0.34	1.07	-0.2	0.04
GBR	2.17	1.82*	-0.36.	0.2.	3.3	2.05.	-0.27	0.27.	-0.75	0.43	-0.19	0.02
GRC	0.94	0.47	-0.47*	0.17.	1.2	0.91	-0.2	0.13.	1.29	0.38	-0.62*	0.07
HUN	-0.19	1.38	-0.29	0.05	-1.54	3.06.	-0.41.	-0.09	0.31	-3.2	-0.02	-0.13
IRL	-0.41	0.24	-0.13	-0.11	-0.56	0.8	-0.09	-0.05	1.19	-1.79	-0.08	0.09
ISL	0.79	0.43	-0.46	-0.1	0.1	1.04.	-0.76*	-0.04	1.84***	-0.53	-0.09	0.08
ISR	0.51	0.17.	-0.69***	0.1	0.39	0.35***	-0.83***	0.1	0.57	-0.32	0.07	-0.06
ITA	-1.61	-0.7	-0.88***	-0.06	0.91	3.46	-0.18	0.06	-3.51	-0.27	-0.61*	-0.11
KOR	0.32	1.03	-0.14	0.05	0.4	0.99	-0.13	0.09	-0.12	1.31***	-0.55***	-0.09
LTU	-0.78	0.68	-0.32	-0.13	0.52	0.95*	-1.04*	-0.02	-0.35	0.74	-0.41.	-0.13
LUX	1.02.	0.79*	-0.47*	0.05	0.4	0.93***	-0.59***	0.03	0.83.	1.04.	-0.28.	0.06
MEX	-3.19	-2.46	-0.29	-0.45	-2.13	-1.98	-0.3	-0.41	-1.52	0.87	-0.2	-0.14
NLD	0.15	-0.06	-0.22	0.07	-2.84.	1.09	-0.27.	-0.06	-0.84	0.6***	-0.87***	-0.03
NOR	3.74	1.93*	-0.66*	0.03	4.49	2.19*	-0.65*	0.04	1.68	6.9	-0.03	0.19.
NZL	-1.93	1.1*	-0.35*	-0.06	-3.52	0.98*	-0.47***	-0.1	0.91	2.33***	-0.1	0.03
POL	-0.43	0.8*	-0.75***	NA	-0.26	0.54*	-0.93***	0	-2.11	1.14***	-0.96***	0
PRT	-2.58.	0.53	-0.46***	-0.1.	-2.86.	-0.15	-0.3*	-0.11.	-0.13	0.59	-0.39.	0.01
SVK	-0.02	1.57.	-0.52.	0.14	-0.78	0.92	-0.43.	0.12	2.04	2.13	-0.31	0.03
SVN	0.6	1.19	-0.28.	0.06	-0.27	0.79	-0.31*	0	-0.28	0.77.	-0.55*	-0.04
SWE	0.1	0.63.	-0.28	0.01	-0.19	1.65***	-0.81***	0.03	0.47	1.11.	-0.36	-0.03
USA	-0.13	1.1.	-0.25.	-0.01	-1.32	2.15	-0.13	0.01	-0.32	1.01.	-0.31*	-0.01

Table AP4. Personal income tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	4.16***	1.23.	-0.19	NA	4.16***	1.23.	-0.19	0	-	-	-	-
AUT	-0.28	1.09*	-0.56***	-0.12	0.59	1.23	-0.23	-0.08	-	-	-	-
BEL	0.44	0.55	-0.22	-0.01	0.6	0.13	-0.15	-0.01	1.47	2.49	-0.14	0.16
CAN	0.93	0.82	-0.23	0.02	1.49.	0.78.	-0.32	0.06	0.04	0.85	-0.18	-0.05
CHE	0.04	1.04.	-0.27.	0.01	-0.86	1.34***	-0.77***	-0.04	0.28	0.95.	-0.29.	0.01
CHL	-2	1.05.	-0.48***	-0.16	-2	1.05.	-0.48***	-0.16	-	-	-	-
COL	-1.45	2.18	-0.11	-0.35	-1.45	2.18	-0.11	-0.35	-	-	-	-
CZE	1.71.	0.64.	-0.48***	0.02	8.07	1.06	-0.51***	0.35	-	-	-	-
DEU	1.34	1.31	-0.15	-0.05	1.21	1.18	-0.31	-0.06	1.35	1.58	-0.11	-0.04
DNK	0.82	0.91.	-0.47.	0.01	0.26	1.52.	-0.36.	0.02	1.29	0.07	-0.23	0.01
ESP	0.53	1	-0.24	-0.01	1.2	-0.32.	-0.84***	-0.08	3.6	4.82***	-0.55***	0.17
FIN	0.6	0.7***	-0.96***	-0.01	1.87.	0.33	-0.34.	0.03	0.33	0.98.	-0.26.	0
FRA	3.89.	2.38.	-0.42.	0.04	3.89.	2.38.	-0.42.	0.04	-	-	-	-
GBR	1.47	1.2.	-0.3	0.02	1.47	1.2.	-0.3	0.02	-	-	-	-
GRC	-0.77	2	-0.08	-0.11	-0.77	2	-0.08	-0.11	-	-	-	-
HUN	1.47	0.59	-0.16	0.07	1.48	0.6	-0.16	0.07	-	-	-	-
IRL	0.09	0.71	-0.23	-0.1.	0.09	0.71	-0.23	-0.1.	-	-	-	-
ISL	1.13***	1.14	-0.15	-0.05	1.62*	1.19.	-0.34.	-0.02	0.94	1.49.	-0.32.	-0.1.
ISR	2.42*	-1.69	0.02	-0.03	2.42*	-1.69	0.02	-0.03	-	-	-	-
ITA	0.73	1.19***	-0.58***	0.04	0.21	0.44	-0.62***	0.01	17.4	28.71*	-0.28.	0.34
JPN	2.5*	5.27***	-0.1	0.03	3.68*	5.26.	-0.1	0.04	0.83	3.37.	-0.16	0
KOR	1.25	1.72	-0.16	0.19	1.23	1.82	-0.14	0.19	1.92	1.57***	-0.53***	0.26
LTU	3.17***	0.46	-0.19.	0.16	3.17***	0.46	-0.19.	0.16	-	-	-	-
LUX	0.17	1.47	-0.13	-0.03	0.17	1.47	-0.13	-0.03	-	-	-	-
MEX	0.73	3.21.	-0.25	-0.06	0.73	3.21.	-0.25	-0.06	-	-	-	-
NLD	-1.56	1.38.	-0.16	-0.08	-1.56	1.38.	-0.16	-0.08	-	-	-	-
NOR	1.29	0.93	-0.26	0.1	0.98	1.6***	-0.74***	0	1.26	0.41	-0.42.	0.12
NZL	2.24***	0.69	-0.17	0.02	2.24***	0.69	-0.17	0.02	-	-	-	-
POL	4.67	0.49***	-0.9***	NA	3.88	-0.03	-0.89***	0	5.43*	1.61***	-0.86***	0
PRT	1.38	0.85	-0.23.	0.07	1.5	0.79	-0.26.	0.07	-	-	-	-
SVK	1.71.	3.98	-0.02	0	1.71.	3.98	-0.02	0	-	-	-	-
SWE	0.76	0.54*	-0.4***	-0.05	-	-	-	-	0.21	1.1***	-0.42***	-0.01
TUR	-0.6	0.78	-0.32.	-0.16	-0.58	0.78	-0.32.	-0.16	-0.8	0.76.	-0.43.	-0.13
USA	4.11*	1.22.	-0.28.	0.01	4.36*	1.21.	-0.28.	0.01	3.02***	1.24.	-0.35.	0.03

Table AP5. Corporate income tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	1.48	1.34.	-0.39.	NA	1.48	1.34.	-0.39.	0	-	-	-	-
AUT	2.06	2.02***	-0.56***	-0.32	2.69	2.38.	-0.39*	-0.31	-	-	-	-
BEL	4.41	2.12.	-0.38.	-0.03	4.41	2.12.	-0.38.	-0.03	-	-	-	-
CAN	6.79***	1.75*	-0.39***	0.19	6.81***	1.68*	-0.34*	0.15	6.2*	1.87.	-0.38*	0.25
CHE	3.08.	2	-0.25	-0.02	3.45	2.62.	-0.49*	0.02	3.18.	1.51	-0.2	-0.04
CHL	7.86***	2.64***	-0.37***	0.09	7.86***	2.64***	-0.37***	0.09	-	-	-	-
COL	1.91	2.41	-0.27	-0.28	1.91	2.41	-0.27	-0.28	-	-	-	-
CZE	2.21	1.04***	-0.51***	-0.01	2.2	1.04***	-0.51***	-0.01	-	-	-	-
DEU	5.39	2.5*	-0.63*	0.05	6.17	1.37	-0.69*	-0.02	5.29	3.1*	-0.54*	0.1
DNK	3.46.	2.03.	-0.42*	-0.17	3.46.	2.03.	-0.42*	-0.17	-	-	-	-
ESP	8.71***	1.86*	-0.29*	0.24.	8.81***	1.87*	-0.3*	0.24	7.65***	1.62	-0.19	0.27.
FIN	2.6	1.74	-0.41*	-0.5	3.16	2.21	-0.38*	-0.53	1.64	0.87	-0.43*	-0.42
FRA	9.12***	1.37*	-0.53***	-0.08	9.12***	1.37*	-0.53***	-0.08	-	-	-	-
GBR	8.22***	1.74***	-0.38***	0.19	8.22***	1.74***	-0.38***	0.19	-	-	-	-
GRC	2.98	1.59	-0.35.	-0.01	2.98	1.59	-0.35.	-0.01	-	-	-	-
HUN	0.23	0.8	-0.4*	-0.23	0.23	0.8	-0.4*	-0.23	-	-	-	-
IRL	1.33***	0.79.	-0.21***	-0.15.	1.33***	0.79.	-0.21***	-0.15.	-	-	-	-
ISL	1.8	2.42***	-0.73***	-0.2	1.89	2.51***	-0.81***	-0.26	-	-	-	-
ISR	5.49***	1.24*	-0.5*	-0.02	5.49***	1.24*	-0.5*	-0.02	-	-	-	-
ITA	1.72	-0.91	-0.27	0	1.47	-1.19	-0.31	-0.01	4.19	12.47.	-0.37.	-0.07
JPN	6.65***	2.56***	-0.25***	0.01	7.24***	2.06***	-0.37***	0.01	5.22*	3.57	-0.15	-0.02
KOR	-0.99	1.4***	-0.85***	-0.33	-0.94	1.37***	-0.85***	-0.33	-1.64	1.74***	-0.71***	-0.34
LUX	0.76	0.81	-0.26	0	0.78	0.91	-0.3	0.01	-	-	-	-
MEX	1.56	4.07*	-0.68*	-0.18	1.56	4.07*	-0.68*	-0.18	-	-	-	-
NLD	6.75***	1.1***	-0.41***	-0.04	6.75***	1.1***	-0.41***	-0.04	-	-	-	-
NOR	4.1	3.01	-0.12	-0.15	3.88	3.17	-0.12	-0.16	-	-	-	-
NZL	3.65.	1.34.	-0.42***	0	3.65.	1.34.	-0.42***	0	-	-	-	-
POL	4.91***	0.95***	-0.37***	NA	4.29***	0.71***	-0.34***	0	10.51.	3.01***	-0.52***	0
PRT	5.96***	2.19***	-0.56***	0.11	6.09***	2.2***	-0.56***	0.11	-	-	-	-
SVK	2.12*	1.52***	-0.33***	-0.01	2.12*	1.52***	-0.33***	-0.01	-	-	-	-
SWE	4.52.	1.37.	-0.53***	0	4.52.	1.37.	-0.53***	0	-	-	-	-
TUR	0.58	1.67	-0.17	0.09	0.48	1.68	-0.16	0.08	1.44	1.59.	-0.33.	0.19
USA	3.88	0.17	-0.28	-0.14	3.8	0	-0.28	-0.19	3.56	0.64	-0.32.	0.03

Table AP6. Social security contribution revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUT	0.19	0.73	-0.15.	-0.02	0.19	0.74	-0.14	-0.02	-	-	-	-
BEL	-0.16	0.83*	-0.35***	-0.01	-0.14	0.83*	-0.35***	-0.01	-	-	-	-
CAN	0.23	0.85.	-0.53*	-0.01	-1.16	0.47	-0.37.	-0.06	15.97.	5.37	-0.28	0.74
CHE	-0.67	0.99.	-0.27*	-0.03	-0.67	0.99.	-0.27*	-0.03	-	-	-	-
CHL	0.4	1.04***	-0.45***	0	0.4	1.04***	-0.45***	0	-	-	-	-
COL	0.38	0.18	-0.46***	-0.01	0.38	0.18	-0.46***	-0.01	-	-	-	-
CZE	1.2***	1.06.	-0.53.	0	1.2***	1.06.	-0.53.	0	-	-	-	-
DEU	0.56	0.93***	-0.51***	-0.01	0.56	0.93***	-0.51***	-0.01	-	-	-	-
DNK	7.55	-1.47	-0.21	0.17	7.55	-1.47	-0.21	0.17	-	-	-	-
ESP	0.67.	1.02*	-0.46*	-0.01	0.67.	1.02*	-0.46*	-0.01	-	-	-	-
EST	0.41.	1.01***	-0.33***	0	0.41.	1.01***	-0.33***	0	-	-	-	-
FIN	0.32	0.66	-0.22.	0.01	0.32	0.66	-0.22.	0.01	-	-	-	-
FRA	-0.4	0.71	-0.21.	0.01	-0.4	0.71	-0.21.	0.01	-	-	-	-
GBR	1.56*	1.38.	-0.3	0.03	1.56*	1.38.	-0.3	0.03	-	-	-	-
GRC	1.06*	0.7	-0.08	0.02	1.06*	0.7	-0.08	0.02	-	-	-	-
HUN	1.24	1.02.	-0.22	0.09	1.24	1.02.	-0.22	0.09	-	-	-	-
IRL	-0.08	1.01***	-0.18***	0.01	-0.08	1.02***	-0.18***	0.01	-	-	-	-
ISL	1.67*	1.35***	-0.58***	0.16	1.67*	1.35***	-0.58***	0.16	-	-	-	-
ISR	0.59.	0.95.	-0.37.	0.01	0.59.	0.95.	-0.37.	0.01	-	-	-	-
ITA	0.22	0.92.	-0.45*	0.01	0.22	0.92.	-0.45*	0.01	-	-	-	-
JPN	0.91***	3.22	0	0.01	0.91***	3.22	0	0.01	-	-	-	-
KOR	0.3	1.81	-0.34.	-0.02	0.3	1.81	-0.34.	-0.02	-	-	-	-
LTU	-0.19	1.15*	-0.37***	-0.06	-0.19	1.15*	-0.37***	-0.06	-	-	-	-
LUX	0.34	1.13***	-0.53***	0.01	0.34	1.13***	-0.53***	0.01	-	-	-	-
LVA	0.05	0.76*	-0.57.	-0.09.	0.05	0.76*	-0.57.	-0.09.	-	-	-	-
MEX	0.58	0.94.	-0.4.	-0.01	0.58	0.94.	-0.4.	-0.01	-	-	-	-
NLD	1.26	0.75	-0.28	0.03	1.26	0.75	-0.28	0.03	-	-	-	-
NOR	0.19	0.95	-0.19	0.06	0.19	0.95	-0.19	0.06	-	-	-	-
POL	0.14	1.01.	-0.38.	NA	0.14	1.01.	-0.38.	0	-	-	-	-
PRT	1.37***	1.57	-0.1	0.02	1.37***	1.57	-0.11	0.02	-	-	-	-
SVK	-0.04	1.2	-0.08	-0.08	-0.04	1.2	-0.08	-0.08	-	-	-	-
SVN	0.33.	1.08***	-0.57***	-0.03.	0.33.	1.08***	-0.57***	-0.03.	-	-	-	-
SWE	0.48	0.38	-0.29.	-0.05	0.48	0.38	-0.29.	-0.05	-	-	-	-
TUR	1.92	1.91	-0.32.	0.14	1.92	1.91	-0.32.	0.14	-	-	-	-
USA	1.51.	0.83.	-0.38.	0.03	1.51.	0.83.	-0.38.	0.03	-	-	-	-

Table AP7. Goods and services tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	1.52	0.87	-0.22	NA	0.45	1.07	-0.25	0	5.06.	0.26	-0.38*	0
AUT	0.6	0.84*	-0.54*	-0.01	0.94	0.58	-0.12	0.02	-	-	-	-
BEL	1.66***	1.04***	-0.58***	0.01	1.66***	0.93*	-0.4*	0.02	1	3.3	-0.38.	0.08
CAN	0.97	0.68	-0.16	0.03	0.95	0.27	-0.2	0.04	1	1.06	-0.07	0.03
CHE	0.02	-1.03	-0.04	-0.05.	0.04	-0.64	-0.05	-0.06.	-0.1	0.64	-0.04	-0.01
CHL	0.35	0.79.	-0.35.	-0.11.	0.35	0.77.	-0.37*	-0.11*	-0.13	1.14.	-0.33*	-0.04
COL	1.52*	1.14.	-0.32.	-0.04	1.67*	1.13.	-0.34*	-0.05	0.74	1.24	-0.08	-0.02
CZE	0.71	1.24*	-0.3.	-0.02	0.74	1.21*	-0.28.	-0.02	-4.69	2.3	-0.39.	-0.3
DEU	0.76.	1.11***	-0.53***	0	1.25.	0.87.	-0.4*	0.04	0.09	1.18.	-0.29***	-0.04
DNK	0.87*	0.72	-0.08	-0.04	0.85*	0.71	-0.09	-0.04	-	-	-	-
ESP	3.92*	1.07***	-0.75***	0.03	3.45.	1.07*	-0.64***	0.01	2.29.	0.9	-0.33.	0.02
EST	0.26	1.09***	-0.78***	-0.13*	0.22	1.08***	-0.81***	-0.14*	-	-	-	-
FIN	0.79*	1.04	-0.17	0	0.8*	1.05	-0.19	0	-	-	-	-
FRA	0.89	1.44	-0.05	0	1.36.	0.65	-0.35.	0	1.79	6.44	-0.11	0.06
GBR	0.78	0.95.	-0.38.	-0.04	0.81	0.97.	-0.4.	-0.04	-	-	-	-
GRC	0.33	0.66	-0.04	-0.02	0.29	0.66	-0.04	-0.02	-	-	-	-
HUN	0.81	1.18.	-0.22	0.06	0.82	1.24	-0.15	0.06	0.06	1.92***	-0.43***	0
IRL	0.19	1.31	0.02	-0.13*	0.21	1.33	0.03	-0.13*	-	-	-	-
ISL	2.25***	0.56*	-0.38***	0.05	2.04***	0.58*	-0.41***	0.04	12.33***	-0.54	-0.27*	0.57
ISR	1.06***	0.94	-0.39	0.04	1.07***	0.94	-0.37	0.05	-	-	-	-
ITA	0.99	0.66	-0.09	0	0.15	0.07	-0.15	-0.03	6.77.	6.87*	-0.5*	0.21
JPN	0.64	2.72	-0.19	0	0.58	2.63	-0.21	-0.01	0.92	3.07	-0.22	0.03
KOR	1.55***	0.98.	-0.32.	-0.04	1.69***	1	-0.22	-0.05	0.99	1.25	-0.17	0.05
LTU	1.24***	0.91.	-0.52.	0.06	1.24***	0.89.	-0.54.	0.06	-	-	-	-
LUX	0.59	0.95	-0.24	0.02	0.52	0.89	-0.21	0.02	-	-	-	-
LVA	0.58	1.21	-0.24	-0.08	0.54	1.19	-0.25	-0.08	-	-	-	-
MEX	2.91***	1.78.	-0.26	0.11	2.92*	1.74.	-0.26	0.11	0	4.12	-0.05	0.03
NLD	1.46***	1.18***	-0.88***	-0.02	1.16***	1.16***	-0.81***	-0.03	6.21.	2.47*	-0.6***	0.17
NOR	1.5	0.49	-0.3.	0.07	1.53	0.49	-0.3.	0.07	0.52	0.01	-0.14	0.05
NZL	0.7	1.02	-0.2	0	0.67	1.01	-0.21	-0.01	-	-	-	-
POL	2.76***	1.02***	-0.76***	NA	2.78***	1.01***	-0.77***	0	0.42	0.55	-0.55***	0
PRT	0.95	1.15*	-0.58*	-0.03	1.02	1.21*	-0.61***	-0.03	-	-	-	-
SVK	0.65	0.95.	-0.34.	-0.05	0.49	0.95	-0.24	-0.05	-	-	-	-
SVN	0.89.	1.02	-0.27	0.02	0.87.	0.98	-0.24	0.02	-	-	-	-
SWE	0.85.	1.06***	-0.98***	0	0.84.	1.06***	-1***	0	-	-	-	-
TUR	1.59*	0.03	-0.07	0.09	1.73*	-0.05	-0.07	0.11	1.39	1.47.	-0.44*	0.04
USA	1.6***	0.84***	-0.61***	0.01	2.46	0.43.	-0.52*	0.03	1.36***	0.92.	-0.39*	0

Table AP8. Payroll tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	-0.58	0.64	-0.25	NA	-	-	-	-	0.89	0.99*	-0.44*	0
AUT	0.14	0.84	-0.19	0	-0.25	0.81	-0.2.	-0.01	1.1	1.04	-0.22	0.01
CAN	0.62	0.87	-0.1	0.02	-	-	-	-	0.62	0.87	-0.1	0.02
COL	10.26	1.3	-0.25.	0.93	10.26	1.3	-0.25.	0.93	-	-	-	-
DNK	-7.2.	0.52	-0.5*	-0.39	-7.2.	0.52	-0.5*	-0.39	-	-	-	-
FRA	-1.3	0.92	-0.08	-0.04	-1.85	0.39	-0.07	-0.04	0.52	2.99.	-0.36*	-0.03
HUN	1.01	1.16	-0.24	-0.24	0.36	1.13	-0.23	-0.36	7.97	-4.52	-0.43.	0.04
ISR	0.09	1.03	-0.09	0.11.	0.09	1.03	-0.09	0.11.	-	-	-	-
KOR	-2.42	0.18	-0.16	-0.52*	-	-	-	-	-0.7	0.92	-0.14	-0.3*
MEX	1.47	2.58.	-0.27	-0.03	-	-	-	-	2.6.	2.77	-0.31	0.03
POL	0.64	1.38***	-0.36***	NA	0.5	1.41***	-0.34***	0	-	-	-	-
SWE	3.17	3.82*	-0.51*	0.04	3.17	3.82*	-0.51*	0.04	-	-	-	-

Table AP9. Property tax revenues

Country	General Government				Central Government				Subnational Governments			
	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy	Shortrun	Longrun	Speed of Adjustment	Dummy
AUS	1.24	1.03.	-0.36.	NA	-	-	-	-	1.05	1.01.	-0.36.	0
BEL	2.47	2.87.	-0.37.	0.05	4	-0.06	-0.27	0.09	0.86	3.89	-0.28	-0.02
CAN	-1.07.	0.85	-0.17	-0.04	-	-	-	-	-1.07.	0.85	-0.17	-0.04
CHE	1.14	0.28	-0.16	-0.02	6.73.	-2.04*	-0.34*	0.1	-0.17	1.04	-0.17	-0.04
CHL	-0.77	0.24	-0.2	-0.17.	-2.19	-0.72	-0.17	-0.49.	-0.29	0.93*	-0.47***	0.02
COL	1.9	-0.75	-0.04	0.69***	2.13	15.73	0.02	7.93***	-0.2	1.69***	-0.3***	-0.04
CZE	0.93	0.81	-0.37.	-0.01	2.51	0.69	-0.47***	0.03	-1.56	1.76	-0.11	-0.06
DEU	0.77	2.18	-0.11	-0.01	-	-	-	-	0.71	1.91	-0.1	-0.01
DNK	0.3	1.18***	-0.52***	-0.01	1.98	0.33	-0.31	-0.04	-0.73	1.67	-0.2.	-0.01
ESP	4.55***	1.85.	-0.44.	0.09	-	-	-	-	4.5***	1.94.	-0.39.	0.09
FIN	2.32***	1.87	-0.14	0.12.	2.11	1.11.	-0.29.	0.08	-	-	-	-
FRA	-0.22	1.52	-0.24	-0.13.	0.53	1.34.	-0.61***	-0.29.	-0.29	0.31	-0.05	-0.02
GBR	3.22*	1.81*	-0.61***	0	1.38	1.29*	-0.53*	0.01	26.18	5.23.	-0.73***	-0.14
GRC	-1.19	0.58	-0.1	-0.13	-1.42	0.7	-0.14	-0.13	0.74	1.82	-0.1	0.05
HUN	-0.84	1.54	-0.1	-0.24.	-7.8	4.42***	-0.93***	-1.62*	0.4	1.53	-0.26	-0.08
IRL	-0.5	0.95	-0.04	-0.43***	-0.59	1.29	-0.05	-0.7***	-	-	-	-
ISL	4.03	0.94*	-1.18***	0.13	8.2	-0.26	-1.27***	0.12	1.09.	1.5*	-0.46*	0.02
ISR	2.18***	1.04***	-0.69***	-0.02	4.59*	1.06***	-0.46***	0	1.27***	0.92	-0.17	0
ITA	-5.6.	-0.92	-0.28*	-0.05	-8.7*	0.07	-0.59***	-0.15	3.95	-7.37	-0.14	0.45
JPN	0.33	-0.01	-0.24.	0.01	0.79	4.79	-0.04	-0.01	0.35	0.48	-0.24***	0.02
KOR	2.51***	1.23***	-0.57***	-0.02	6.74***	2.03***	-0.66***	0.38	1.17	0.94.	-0.35.	-0.15
LUX	2.01.	1.4*	-0.33.	-0.09	2	1.42*	-0.33.	-0.1	-	-	-	-
MEX	1.16	1.49	-0.16	0.01	-	-	-	-	1.16	1.49	-0.16	0.01
NLD	2.14.	0.72	-0.26.	-0.04	4.18.	0.71	-0.3*	-0.12	-1.02	0.69	-0.24	-0.02
NOR	2.22.	1.48.	-0.26	0.09	2.51	1.97*	-0.37.	0.1	1.21	11.48	-0.01	0.09
NZL	0.71	1.16***	-0.29***	0.01	-	-	-	-	0.65	1.21***	-0.32***	0.03
POL	-0.05	0.94	-0.28.	NA	-	-	-	-	-0.05	0.94	-0.28.	0
PRT	4.97***	2.74***	-0.71***	0.07	-	-	-	-	2.47*	2.79	-0.24	0.01
SWE	-0.4	-0.07	-0.36.	-0.11	-1.4	-1.51*	-0.25*	-0.27*	-	-	-	-
TUR	2.39	1.95***	-0.96***	0.4	2.02	1.75***	-0.98***	0.37	-0.61	0.88	-0.08	-0.44
USA	0.86	1.07***	-1.06***	0.04	12.25	0.7	-0.91***	0.35	0.2	1.01*	-0.3***	0.02