Online Annex 2.1. Estimating the Revenue Impact of Pillar 1 and 2

This annex describes the calculations for Figures 2.2 and 2.3 in Chapter 2. First, it describes the simplified empirical measures for decomposing multinationals' profits into 'normal' and 'excess' profits and then details the methodology used to estimate the static revenue impacts of Pillars 1 and 2 of the Inclusive Framework agreement, along with a sensitivity analysis.

Decomposing Total Profit

Total multinational profit is USD 7.9 trillion according to S&P Capital IQ's database on consolidated accounts of the largest 40,000 (public and private) multinationals.[1] Table 2.1.1 shows the dataset's coverage and profit by sector,[2] with the Industrials, Energy, and Financials earning the most profit, and Energy, Communication Services, and Utilities having the highest average profit per firm. Profit is concentrated in relatively few, very large firms—42 percent of profit is earned by the 400 firms with the highest earnings (1 percent of the sample) and 80 percent of total profit is earned by 4,000 firms (10 percent of the sample).

Online Annex Table 2.1.1. Total Multinational Profit by Sector

Sector	Total firms	Profit (USD millions)				
		Total	Average	Median	25th percentile	75th percentile
Energy	1,642	1,169,364	712	73	14	272
Financials	3,608	799,258	222	12	0	78
Communication Services	1,413	579,386	410	39	11	164
Consumer Discretionary	6,522	765,149	117	16	6	52
Consumer Staples	3,748	551,323	147	17	5	55
Industrials	10,094	1,319,351	131	20	7	62
Materials	4,068	663,407	163	27	10	90
Real Estate	1,800	392,115	218	75	25	177
Utilities	1,991	651,297	327	84	22	259
Health Care	2,257	454,890	202	23	8	69
Information Technology	3,025	560,789	185	19	8	54
Undefined	433	19,141	44	10	3	30
All	***40,601***	***7,925,470***	***195***	***23***	***7***	***82***

Sources: IMF estimates using S&P Capital IQ data.

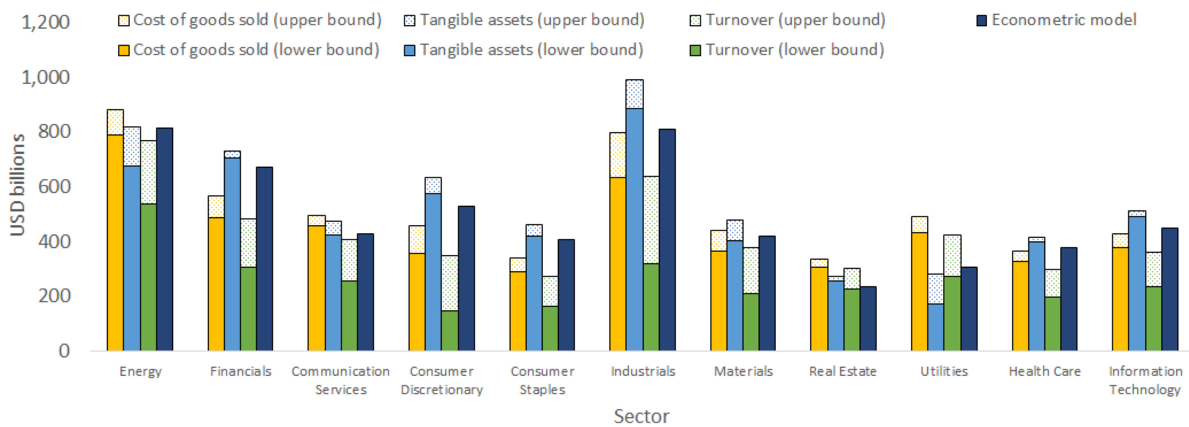
For each multinational, excess profit is computed as total profit minus normal profit, and then summed up for different groupings (e.g., headquarter country and sector), using four separate measures of normal profit: (i) 5-7.5 percent of the cost of goods sold, (ii) 5-7.5 percent of tangible assets, (iii) 5-10 percent of turnover, and (iv) an estimate based on an econometric model (described in Box 2.1.1).

Under all methods, the Energy, Industrials, and Financial sector have the largest excess profit, but the magnitude and order vary.

[1] Multinationals with negative profit and missing values for assets and/or payroll are excluded from the sample, reducing the dataset from 50,000 to 40,000 multinationals. The removed multinationals are relatively small.

[2] Profit is defined as earnings before interest and tax (EBIT). The aggregate across firms in the dataset for EBIT and EBT (earnings before tax) are similar (e.g., the difference is roughly 1 percent).

Online Annex Figure 2.1.1. Multinational Excess Profit by Sector



Sources: IMF estimates using S&P Capital IQ data.

Online Annex Box 2.1.1. Bottom-up Estimates of Residual Profits

The bottom-up estimates of residual profit at the firm-level are based on the following regression specification (Beer and Loeprick, forthcoming):

$$\ln\,(\pi_{its}) = \alpha_s ln(\,\mu_{its}) + \beta_s \ln\,(1+\rho_{its}) + \gamma_s' X_{its} + \varepsilon_{its,} \qquad \text{(A.1.)}$$

where π_{ist} is earnings before taxation, $(\alpha_s, \beta_s, \gamma_s')$ is an industry-specific vector of regression coefficients, μ_{its} is a firm-specific measure of output prices over marginal production cost in year *t* and industry *s*, computed following De Loecker and others (2020), ρ_{its} is a firm-specific measure of risk, computed using the firm's optimization condition for capital inputs when risk-premia vary (thus, here firm-specific risk is part of the normal return), and X_{its} is a vector of control variables that includes firm-specific productive inputs (assets, employees) and macro variables (including GDP, GDP growth, and inflation), and ε_{its} is an idiosyncratic residual that is uncorrelated with productive inputs, risk, and market power. We define routine profit as the earnings a subsidiary should expect in the absence of market power and risk. The average share of routine profit given a firm's tangible assets, k_{its}, on an industry-level, is defined as

$$\mathrm{P_s} \equiv \frac{1}{N_s} \sum_{it} \frac{\mathrm{e}^{\left(\widehat{\gamma_s'} X_{its}\right)} \mathrm{e}^{\left(\frac{\sigma^S}{2}\right)}}{k_{its}},$$

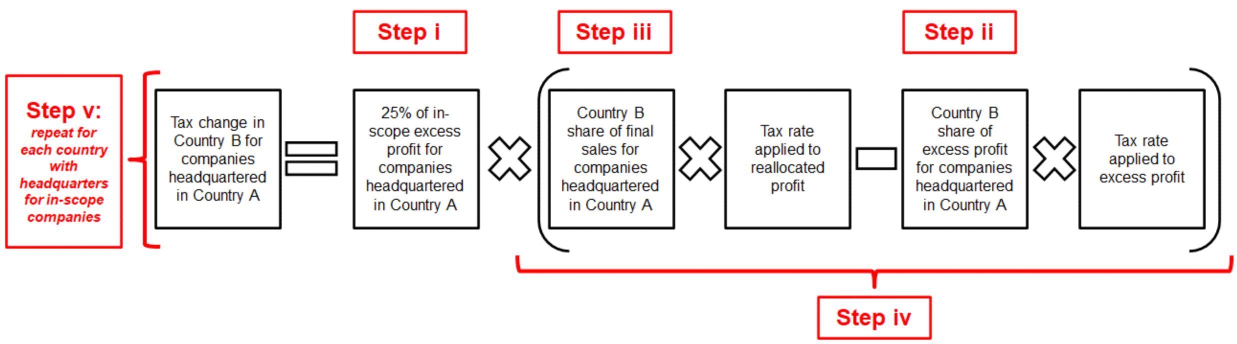
where $\widehat{\gamma_s'}$ are estimated coefficients from equation (A.1.), relying on a panel dataset of independent firms operating in industry s, comprising N_s observations, and σ_s^2 is the estimated variance of the residual in (A1). Estimates of routine and residual profit for MNEs' consolidated accounts follow from using $Routine_{is} = \mathrm{P}_s k_{is}$, and $Residual_{is} = \pi_{is} - Routine_{is}$, where k_{is} are tangible assets and π_{is} is earnings before taxation as recorded in the S&P Capital IQ database.

Pillar 1: Static Revenue Estimate

Pillar 1 reallocates 25 percent of in-scope multinationals excess profit to the jurisdiction where multinationals make final sales (i.e., the market jurisdiction)—the amount of reallocated profit is called Amount A under Pillar 1. To estimate the revenue impact of Amount A for individual countries, the calculation uses five steps, which are described below and depicted in Figure 2.1.2.

i. calculate 25 percent of the global excess profit for in-scope multinationals from a given headquarter country (e.g., 25 percent of global excess profit for in-scope multinationals from Country A),
ii. determine the share of excess profit in each source country from a given headquarter country[3] (e.g., the excess profit of multinationals from country A in country B as a share of global excess profits by country A's multinationals),
iii. determine the share of final sales for each source country from a given headquarter country (e.g., the final sales of multinationals from country A in country B as a share of global final sales by country A's multinationals),
iv. apply the rate applicable to currently taxed (step ii) and reallocated excess profit (step iii) to determine the gain/loss from Amount A of Pillar 1 for each source country from a given headquarter country (e.g., the increase/decrease in tax revenue of multinationals from Country A in Country B),[4] and
v. repeat steps (i) through (iv) for each headquarter country to calculate the total gain/loss from Amount A of Pillar 1.

Online Annex Figure 2.1.2. Methodology for Pillar 1 Static Revenue Estimate



Note: the above calculation is repeated for all headquarter countries and then summed together to determine the total revenue impact on Country B. The diagram is similar to Figure 2.1 in OECD 2020. Excess profit is defined as profits above 10 percent of turnover.

For step (i), the computation uses the S&P Capital IQ dataset and first excludes all out-of-scope firms (i.e., those with turnover below EUR 20 billion and those in the extractive or regulated financial sector) from our dataset. Next, the chapter calculates excess profit, assuming that excess profit is equal to profit above 10 percent of turnover.[5]

The method used to estimate excess profit reported in source-headquarter country pairs (step ii) varies by headquarter country, based on data availability. If the country has country-by-country (CBC) data with financial indicators reported for many source jurisdictions,[6] then excess profit is calculated using CBC data at

[3] The source country is the location in which a multinational produces goods and services, while the market jurisdiction is the location of final sales.

[4] This approach generally follows that of the static revenue estimate in the OECD's Economic Impact Assessment (2020).

[5] This results in around 140 companies with excess profit—they are headquartered in 25 countries (19 advanced and 6 emerging market countries), with 46, 12, 6, and 6 percent of excess profit from multinationals headquartered in the United States, China, United Kingdom, and Hong Kong SAR, respectively.

[6] These headquarter countries are Australia, Bermuda, China, Denmark, France, Germany, India, Italy, Japan, Luxembourg, Mexico, South Africa, Spain, Switzerland, and United States.

the source-headquarter country level for multinational sub-groups[7] with positive profit (e.g., total profit less 10 percent of turnover of country's A multinationals in country B). If the headquarter country's CBC data groups many countries together (e.g., profit reported for all of Asia or all foreign jurisdictions, without reporting for individual countries) or there is no CBC data, then the allocation of excess profits by source country is assumed to match the simple average for headquarter countries that report comprehensive CBC data.

The method to estimate final sales in source-headquarter country pairs (step iii) generally follows the methodology from (step ii), using CBC data and other data sources, such as the US Bureau of Economic Activity (BEA) survey on US Multinational Activities and the OECD's Activity of Multinational Enterprises (AME) dataset. These datasets report revenue by source country, which needs to be adjusted to account for revenue that is not connected to the market jurisdiction (i.e., related party sales). This adjustment is done by assuming re-export ratios that come from the US BEA and apportioning the re-exported revenue based on the source countries' bilateral trade destinations, coming from the World Banks WITS database (e.g., re-exports from country A are allocated to individual countries based on the share of country A exports to each individual country). Final sales for each source country equal the multinational domestic sales to final consumers plus imports, stemming from re-exports.

In step (iv), the tax rate for current excess profits (step ii) and excess profits reallocated using sales by destination (step iii) must be defined. Reallocated excess profits are assumed to be taxed at the statutory corporate income tax (CIT) rate, while three separate methods are used for the tax rate applicable to the current excess profit since the statutory CIT rate does not apply in all cases (for example, when there are preferential regimes for foreign-sourced income). The separate methods for current excess profit serve as sensitivity analysis because there is no available data on the actual tax rate applied to these profits. The three excess profit tax rate methods are: (i) the statutory CIT rate, (ii) the source-headquarter country effective tax rate estimated using CBC data, with profit adjusted downward since dividends are included in profit in the CBC data (in some cases) and dividends are generally exempt or lightly taxed—profit is reduced by 17 percent for all countries, which matches the adjustment needed for Netherlands based on OECD 2020b,[8] and (iii) the source country's effective tax rate estimated using US BEA data (profit from the US BEA is the profit-type return series and, therefore, excludes income from equity investment and does not require an adjustment to remove dividends).

Step (v) is to sum together the revenue gain/loss for a given source country because, up to this point, the chapter only computes the revenue gain/loss for each source-headquarter country pair. The result is the total revenue gain/loss from Amount A of Pillar 1.

Pillar 2: Static Revenue Estimate

Pillar 2 of the Inclusive Framework applies a top-up tax to profits of in-scope multinationals that are taxed below 15 percent in any given source country. A portion of profit is excluded from this minimum tax. This portion is called "substance-based carve-out" (a tax deduction for assets and payroll). It is calculated using the indicator for tangible assets from the CBC dataset and an estimate for payroll.[9] Profit, assets, and payroll are adjusted downward to exclude the amounts attributed to the headquarter country, effectively removing any

[7] A sub-group is composed of all entities located in a single jurisdiction that are owned by a single parent company.

[8] OECD 2020b compared CBC profit with that reported in tax returns and found that 17 percent of profit was made up of dividends. See OECD 2021 for a full description of data limitations.

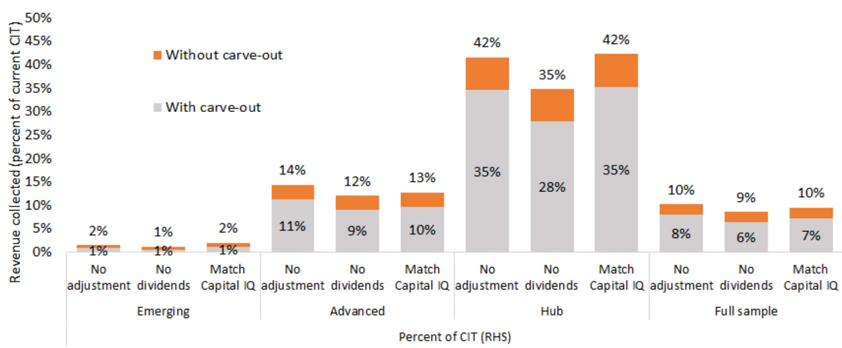
[9] The CBC data only includes information on the total number of employees, not payroll. The annual wage paid to each employee was calculated for each source country using the US BEA data on payroll and employees.

revenue from Pillar 2 that could stem from profits taxed below 15 percent located in the headquarter country.[10]

To estimate the revenue implications of Pillar 2, two methodologies are used (depending on data availability for a given country)[11]—depending on whether a country provides financial indicators based on the effective tax rate paid by multinational sub-groups.[12] For countries that provide these indicators (with the exception of Switzerland),[13] the profit after carve-out was assumed to be taxed at 15 percent (for the negative income tax accrued bracket) and 10 percent (for the 0-10 percent tax rate bracket), with all other profit assumed to be taxed at more than 15 percent.[14] For countries without these indicators, the effective tax rate is calculated for sub-groups with positive profits by source-headquarter country pair and then a top-up tax is applied to profit (after a deduction for the carve-out) in cases where the effective tax rate is less than 15 percent. Profits are adjusted downward to account for non-taxable dividends, as with the calculation for Pillar 1.

As a sensitivity analysis, three estimates are produced (Figure 2.1.3): (i) adjustments for dividends using the methodology applied for Pillar 1, (ii) no adjustment for dividends, and (iii) adjustment to profit so that aggregate profit for multinationals from each headquarter country matches that of in-scope profit from the S&P Capital IQ dataset. The various methods do not have a large impact on the results aggregated by country grouping. These estimates focus only on a top-up tax on in-scope multinationals without considering, for example, the revenue impact of raising the corporate income tax rate on non-multinational or out-of-scope multinational corporations.

Online Annex Figure 2.1.3. Pillar 2 Revenue Estimate, Sensitivity Analysis



Sources: IMF estimates using data from S&P Capital IQ, OECD CBC, US BEA, and other data sources.
Note: Carve-out refers to a deduction when calculating the tax base to which Pillar 2 applies. The deduction is equal to 10 percent of payroll costs and 8 percent of tangible assets.

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[10] Emerging market multinationals earn a large portion of their profit within the headquarter country. For example, 89, 83, and 80 percent of total profit for Chinese, Indian, and Brazilian multinationals was earned domestically (85 percent for emerging market multinationals on average), compared to 53 percent for advanced economies.

[11] Calculations are not done for jurisdictions without CBC reporting. In-scope MNEs in those jurisdictions represent 9 percent of total global in-scope profit, with the two most important, omitted jurisdictions being Hong Kong and Taiwan.

[12] Titled 'Table IV – Aggregate totals by tax rate of MNE sub-groups' in the 2017 OECD CBC dataset. Out of the 38 countries with CBC data, the only countries not providing Table IV are Bermuda, China, Latvia, Isle of Man, Romania, and Switzerland.

[13] Switzerland uses the other method because profit reported under Table IV exceeds USD 500 trillion, which is far more than that reported under other tables.

[14] Results are relatively insensitive to whether profit with effective tax rates of 10 to 20 percent is assumed to be undertaxed and, thus, subject to a small top-up tax.

Revenue estimates for Pillar 2 have been also reported in (OECD 2020a) and (Barake 2021; EU Tax Observatory). The chapter estimates that Pillar 2 revenue is 4.8 percent of total CIT collections compared to 7.4 percent in Barake (2021) for countries that overlap between both studies.[15] In most cases, country-level estimates are similar (less than 5 percent difference), with the revenue gain significantly higher under Barake for a few select countries. OECD (2020a) estimates that total CIT collections for all countries (excluding the US) is 1.2-1.5 percent, while this chapter estimates it at 4.4 percent.[16] The OECD used a similar methodology but with different data vintages (e.g., 2016 CBC data, rather than 2017) and some different assumptions (e.g., the assets portion of the carve-out equals to 10 percent as was proposed at the time). The chapter does not estimate the impact of Pillar 2 if source countries impose a top-up tax (rather than the headquarter country).

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[15] Excluding a top-up tax on undertaxed profits earned domestically and the US. The US is excluded because the US has a minimum tax (so-called GILTI), which takes precedent and, therefore, Pillar 2 will likely not apply to the US if GILTI is changed to be computed on a country-by-country basis. Barake (2021) includes undertaxed domestic profit in its base case scenario but disaggregates undertaxed profits by domestic and foreign earned in the Appendix.

[16] These estimates were extrapolating to all countries by assuming that countries without CBC reporting but with in-scope multinationals match the same pattern as those with CBC data.

Online Annex 2.2. Corporate Tax Rate Strategic Reaction

This annex presents estimates of the reaction of the corporate income tax (CIT) rate in one country to CIT rate changes in the rest of the world as referred to in Chapter 2. Specifically, a one percentage point change in the average foreign CIT rate leads the home rate to change by up to 0.6 percentage points in the same direction. To illustrate, if one country cuts its CIT rate, what is the best response of the others? Theoretically, this best response (or slope of the reaction function) can be positive or negative. Empirically, the magnitude of the slope has not been tied down with precision due to identification challenges, but overall existing empirical studies suggest that it is positive (that is, CIT rates are strategic complements)—as surveyed for example in Leibrecht and Hochgatterer (2012) and OECD (2020). Acknowledging the empirical challenges and building on the literature, this annex estimates the slope of the CIT rate reaction function and the likelihood of a discrete rate cut. The implicit assumption is that a government weighs unobservable and time-varying domestic preferences toward the CIT rate against the level of the average foreign CIT rate.

Empirical Specification

Changes to the domestic CIT rate of country *i* in year *t* (τ_{it}) occur endogenously at any time t^* when the deviation of the government's optimal CIT rate (a weighted-average of an unobservable domestic preference and the average foreign CIT rate) from the current rate is large enough.[1] The new tax rate is a function of the contemporaneous foreign CIT rate $\tau^f_{it^*}$ and past domestic and foreign tax rates at time $t^* - s^*$(the last time when the domestic CIT rate was changed):

(1) $$\tau_{it^*} = \beta_1 \tau^f_{t^*} + \beta_2 \tau_{it^*-s^*} + \beta_3 \tau^f_{t^*-s^*} + \epsilon_{it^*}.$$

The variable ϵ_{it^*} is an error term. A companion equation gives the probability, based on a logit discrete choice model, whereby a decrease in the domestic CIT rate is observed at time t

(2) $$\log \frac{\pi_{it}}{1-\pi_{it}} = \gamma_1 \tau^f_t + \gamma_2 \tau_{it-s} + \gamma_3 \tau^f_{t-s},$$

where π_{it} is the probability that a tax decrease is observed in year t. Note that while regression (1) is run only on sample years t^* where the CIT rate has a change, the logit model (2) is estimated using all years in the sample.

Equations (1) and (2) are estimated in two versions, one with only country fixed effects—that control for unobserved time-invariant heterogeneity across countries—and one that additionally includes a linear time trend. The linear trend addresses potential cross-country correlation of the shocks that drive the evolution of the latent domestic preference over the level of the CIT rate.[2] The sample includes 133 countries during 1960-2019. CIT rates have been falling with frequent discrete changes (Figure 2.2.1). Following the literature, $\tau^f_{it^*}$ is calculated as a weighted average of the CIT rate in all foreign countries, weighted by their inverse distance from the home country.

Results

Tables 2.2.1-2 report the estimation results for (1) and (2), respectively. Each table presents estimates for different samples and for the two versions of the model that we consider (with or without time trend). Overall, a 1 percentage point higher foreign CIT rate leads to an increase in the domestic CIT rate of between 0.25 and 0.60 percentage points, depending on the sample. This finding is in line with other estimates in the

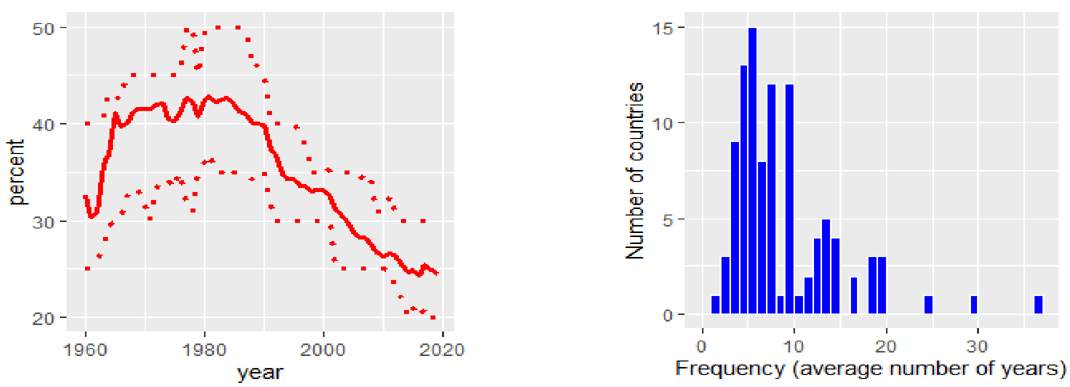
[1] For brevity, the annex reports only the equilibrium equations of the model without presenting their full derivation.

[2] The concern is that common shocks over time may have caused a simultaneous change across countries in their domestic preference for corporate income taxation.

literature based on different methodologies. For example, Devereux and others (2008) find that a 1 percentage point cut in the average foreign statutory rate lowers the rate at home between 0.34 and 0.67 percentage points, in a sample of advanced economies. Crivelli and others (2016) estimate the effect at 0.25 to 0.3 points, in a sample that includes also developing economies. This means that if a binding minimum tax raises the rate of some countries, the others will likely react by raising their rates too (Hebous and Keen, 2021). If below-minimum countries raise their rates to the minimum—and in turn other countries raise their rates by 0.6 percentage points in reaction to each 1 percentage point increase in the world average rate—the average world corporate income tax rate would rise from 22.2 to 24.3 percent. This in turn increases global corporate tax revenues by about 8.1 percent (after removing the top-up tax base to avoid double counting). Finally, for further insights, Table 2.2.2 indicates that a 1 percentage point higher foreign CIT rate reduces the average probability of observing a decrease in the domestic CIT rate by between 0.8 and 1.2 percentage points per year. This translates into a probability of roughly 10 percentage points over 10 years.

Online Annex Figure 2.2.1. CIT Rates

1. Average CIT Rate Trend **2. Frequency of CIT Rate Changes (1960-2019)**



Source: IMF staff estimates
Note: Lines in panel (a) indicate the mean and the top and bottom quartiles. Panel (b) depicts the number of countries that display a given frequency of CIT rate change, measured as the average number of years between two consecutive changes.

Online Annex Table 2.2.1. Estimates of the CIT Rate Reaction

Sample	*Foreign t**	*Domestic t*- s**	*Foreign t*- s**	*Trend*	*R^2 adjusted*	*Obs.*
All	0.591***	0.376***	-0.093		0.51	124
	(0.059)	(0.031)	(0.06)			
All	0.344***	0.382***	-0.1*	-0.167***	0.52	124
	(0.08)	(0.031)	(0.059)	(0.037)		
OECD	0.559***	0.512***	-0.133		0.66	32
	(0.086)	(0.043)	(0.092)			
OECD	0.416***	0.513***	-0.133	-0.097**	0.67	32
	(0.111)	(0.043)	(0.092)	(0.047)		
Non-OECD	0.603***	0.271***	-0.072		0.33	92
	(0.081)	(0.043)	(0.078)			
Non-OECD	0.248**	0.288***	-0.089	-0.235***	0.36	92
	(0.115)	(0.042)	(0.077)	(0.056)		

Source: IMF Staff estimates.
Note: OLS regressions with country fixed effects and robust standard errors. The inclusion of standard macroeconomic controls has no impact on the estimates.

Online Annex Table 2.2.2. Likelihood of a CIT Cut (Average Marginal Effect)

Sample	*Foreign t*	*Domestic t_s*	*Foreign t_s*	*Trend*	*Deviance*	*Deg. Freedom*	*Obs.*
All	-0.012***	0.014***	0		2724	3780	3916
	(0.002)	(0.001)	(0.002)				
All	-0.008***	0.015***	0	0.002**	2720	3779	3916
	(0.002)	(0.001)	(0.002)	(0.001)			
OECD	-0.013***	0.017***	-0.002		1124	1263	1298
	(0.004)	(0.002)	(0.004)				
OECD	-0.008*	0.017***	-0.002	0.003	1122	1262	1298
	(0.005)	(0.002)	(0.004)	(0.002)			
Non-OECD	-0.011***	0.014***	0		1598	2514	2618
	(0.002)	(0.002)	(0.002)				
Non-OECD	-0.008***	0.014***	0	0.002*	1594	2513	2618
	(0.003)	(0.002)	(0.002)	(0.001)			

Source: IMF staff estimates.
Note: Deviance and degrees of freedom correspond to the model in logit form, which is estimated via maximum likelihood, and includes country fixed effect. The inclusion of standard macroeconomic controls has no impact on the estimates.

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Online Annex 2.3. Survey of International Coordination and Tax Administration

This annex summarizes the results of a survey of 72 countries on the scope of international tax cooperation (ITC) that is used in Figure 2.4 in Chapter 2. The survey comprised nine questions, focusing on the number and types of tax cooperation relationships and exchanges, the use of the information by the tax administration, as well as the types of challenges encountered that may prevent the maximum benefit being realized from the tax cooperation arrangement.[1]

ITC is increasingly used to improve revenue outcomes for tax administrations, enhance transparency, address information asymmetry between global taxpayers and national tax administrations, and deter offshore tax avoidance and evasion. The Global Forum on Transparency and Exchange of Information for Tax Purposes is the leading international body working on the implementation of global transparency and exchange of information standards. Information exchange mechanisms include bilateral and multilateral tax treaties, Tax Information Exchange Agreements[2] (TIEA-a bilateral agreement between two tax authorities to share information as defined in the agreement), and the Multilateral Competent Authority Agreement[3] (MCAA-an agreement among multiple tax jurisdictions to share information), Common Reporting Standard (CRS-sets out the types of financial account and taxpayer information to be shared automatically by financial institutions, and specifies the methodology to ensure standardized content and format)[4] and Country by Country Reporting (CBC-requires multinationals (with a global turnover exceeding €750 million) to prepare a CBC report of the global allocation of its income, assets, and other indicators among tax jurisdictions in which it operates).[5]

Types and Use of Information Exchanges

The survey identified the average number of information exchange relationships currently in place in the surveyed countries (Figure 2.3.1). Segmenting the information between EMEs, LIDCs, and AEs, a notable disparity among the groups is evident. The number of exchange relationships in place increases markedly from Low-Income Developing Countries (LIDCs) compared to Emerging Market Economies (EMEs) and further increases in Advanced Economies (AEs). Given the low number of AEs who responded to the survey, the results for this income group may not be representative, and any conclusions should be interpreted with caution. The number of exchange relationships reported in AEs is almost three times more than what is reported in EMEs. The same ratio is noted when reported exchange relationships in EMEs are compared against LIDCs.

Exchange of Information on Request (EOIR) is widely used and other newer types of EOI are increasingly being used. These newer types of EOI include EOIR-sharing of rulings, Automatic Exchange of Information – Country by Country Reporting (AEOI-CBC) and AEOI-Financial Account Information. As noted in Figure 2.3.1, the 2019/2020 data for LIDCs indicates incoming EOIR requests received by 40 percent of countries while outgoing requests were noted by 44 percent of LIDC countries. For EMEs, the percentage of countries reporting incoming requests is 74 percent, and for outgoing is 77 percent. All AE respondents participate in incoming and outgoing EOIR. High rates of usage for EOIR are expected as this type of exchange relates to a particular taxpayer and the information is typically used in connection with an ongoing

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1 The survey was administered in August 2021. Of the 72 countries who responded, 8 are from advanced economies (AE), 39 are from emerging market economies (EME) and 25 are from low income developing countries (LIDC). Results, as with any survey, should be interpreted with caution.

2 https://www.oecd.org/ctp/exchange-of-tax-information/taxinformationexchangeagreementstieas.htm

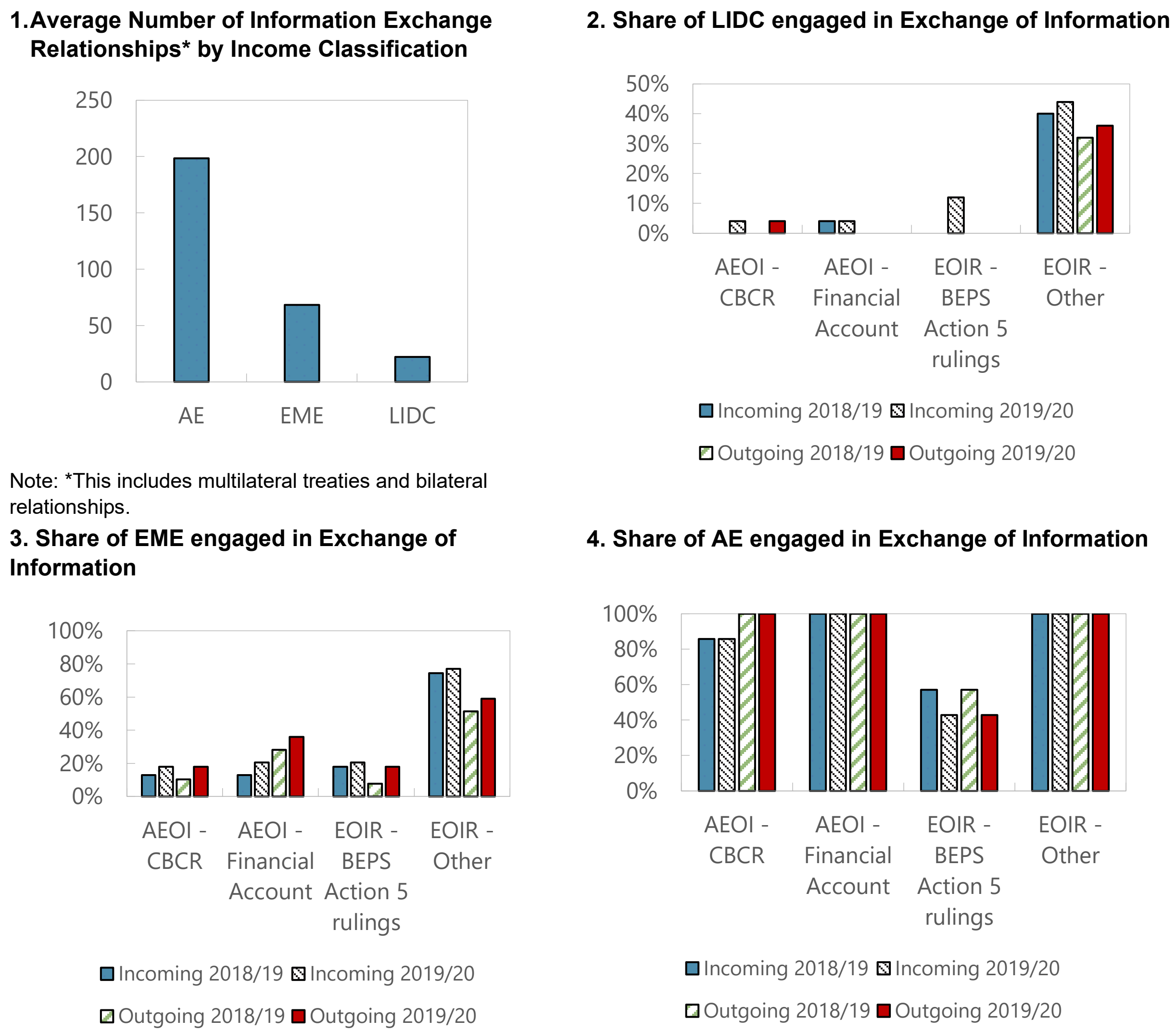
3 https://www.oecd.org/tax/transparency/documents/whatisthemultilateralcompetentauthorityagreement.htm

4 https://www.oecd.org/tax/automatic-exchange/common-reporting-standard/

5 The report is shared with tax administrations in these jurisdictions: https://www.oecd.org/tax/beps/beps-actions/action13/

audit in the requesting country. Given EOIR has been in existence the longest, the higher usage of this type of exchange is expected.

Online Annex Figure 2.3.1. Types and Usage of EOI by Income Classification[6]



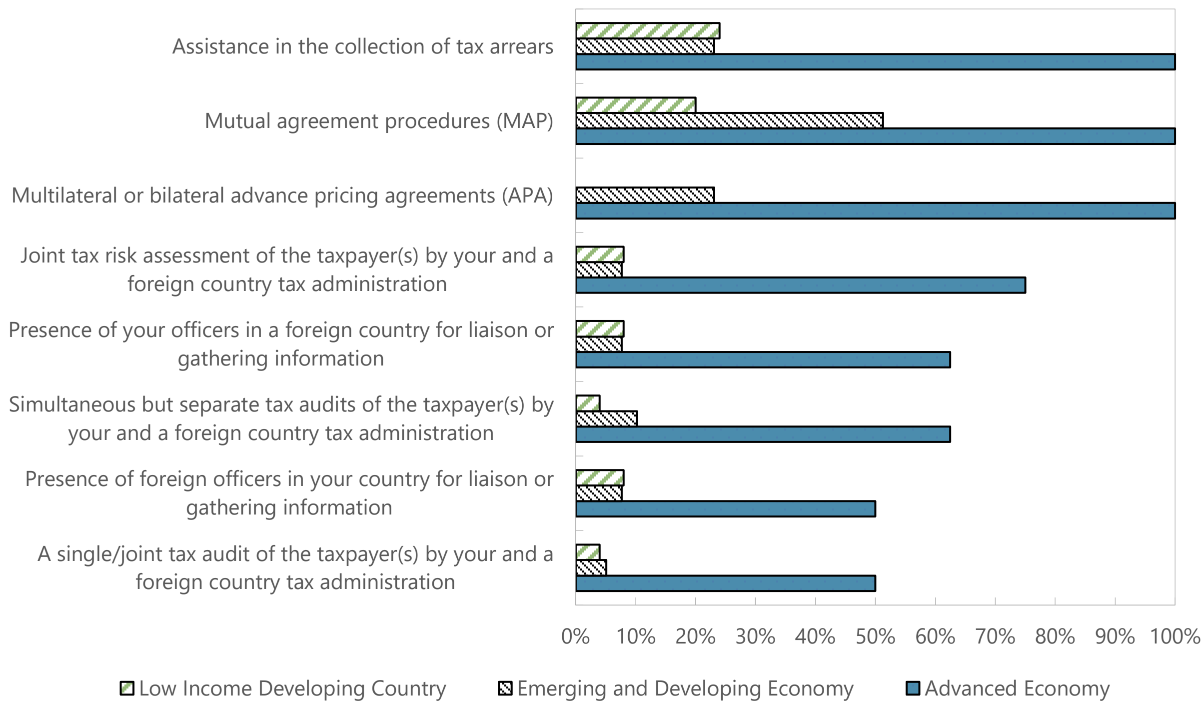
Source: Compiled by IMF staff based on a survey.

[6] AEOI on financial accounts is designed to identify global offshore tax evasion by a taxpayer holding financial assets in foreign countries (in foreign banks and other financial institutions). This is identified by requiring the annual exchange of predetermined information by countries on financial assets (e.g., interest, dividends, other income) held by foreigners in the country. EoI on Action 5 rulings is an important tool to prevent countries from providing preferential tax treatment in the form of rulings to MNEs, and it helps countries have a comprehensive view of a MNEs' global dealings and transactions.

Other Types of International Tax Cooperation

Beyond EOI, other methods of tax cooperation[7] were found to be used less frequently. Of these types of tax cooperation, the most popular among AE countries is mutual agreement procedures MAP)[8], Advance Pricing Arrangements (APA)[9], and collection of tax arrears, with 100 percent of AE countries indicating that they had participated in these three types of ITC. For LIDCs and EMEs, the most popular responses were MAP and assistance in collection of tax arrears. APAs were used by 23 percent of EME countries. As noted in Figure 2.3.2, other types of tax cooperation are less used by EMEs and LIDCs, with no more than 10 percent of countries indicating that they used any of the remaining other types of tax cooperation. ITC in all its forms is important as it represents peer to peer learning opportunities (joint and simultaneous audits and risk assessment), while MAP could provide tax certainty and help avoid disputes and double taxation.

Online Annex Figure 2.3.2. Share of Countries Using Other Types of ITC



Source: Compiled by IMF staff based on a survey.

Revenue Impact of International Tax Cooperation

As noted in Figure 2.3.3, 38 percent of AE countries impose additional tax, compared to 31 percent for EMEs and 20 percent for LIDCs. This gap in the rates of tax assessments among countries represents

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[7] Other methods of ITC include: (i) Joint tax risk assessment of a taxpayer; (ii) Presence of officers in a foreign country for liaison or gathering information; (iii) Presence of foreign officers in your country for liaison or gathering information; (iv) Simultaneous but separate tax audits of taxpayers; (v) A single/joint tax audit of a taxpayer; (vi) Assistance in the collection of tax arrears; (vii) Mutual agreement procedures (MAP); (viii) Multilateral or bilateral advance pricing agreements (APA).

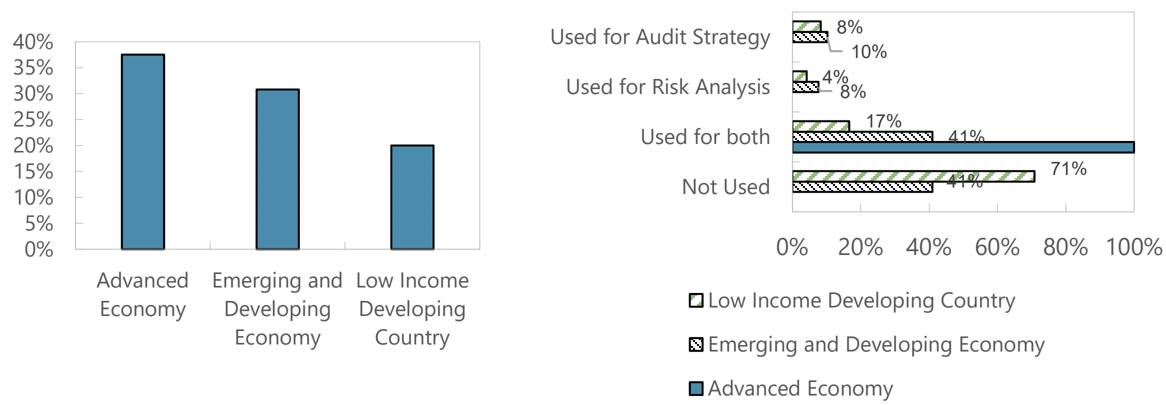
[8] MAP is a negotiation between country authorities to resolve or prevent double taxation.

[9] An APA is an agreement between the tax administration and the taxpayer that sets pricing for the related party transfer of goods and services for a defined period of time.

potential additional revenue for both EMEs and LIDCs. An opportunity exists to strengthen revenue further through enhanced usage of the information received. 41 percent of EMEs and 71 percent of LIDCs have not used the information received through exchange mechanisms to improve their risk assessment processes or their audit strategy (Figure 2.3.3). Data received from external sources provides a view of taxpayer risks and compliance levels that the tax administration otherwise would not have.

Online Annex Figure 2.3.3. Revenue Impact of ITC – Present and Future Potential

1. Share of Countries with Tax Assessments Resulting from ITC **2. Exchanged Information And Compliance**



Source: Compiled by IMF staff based on a survey.

Challenges in Using Information Received through Information Exchange

To determine why the information may not have been used to its full potential, countries were asked to rate challenges[10] related to the exchange and use of information. This feedback can help identify priorities for a country's reform plan and identify capacity development opportunities. Among both EMEs and LIDCs, the biggest challenges in exchanging and using information were reported as inadequate information technology (IT) infrastructure, inadequate legal provisions to request information from other countries, and inadequate knowledge about the concept of EOI in the organization. For AEs, the challenges reported were rated low in comparison with other income classifications, with the biggest issues relating to quality of incoming data and long response times to requests. Figure 2.3.4 presents the results.

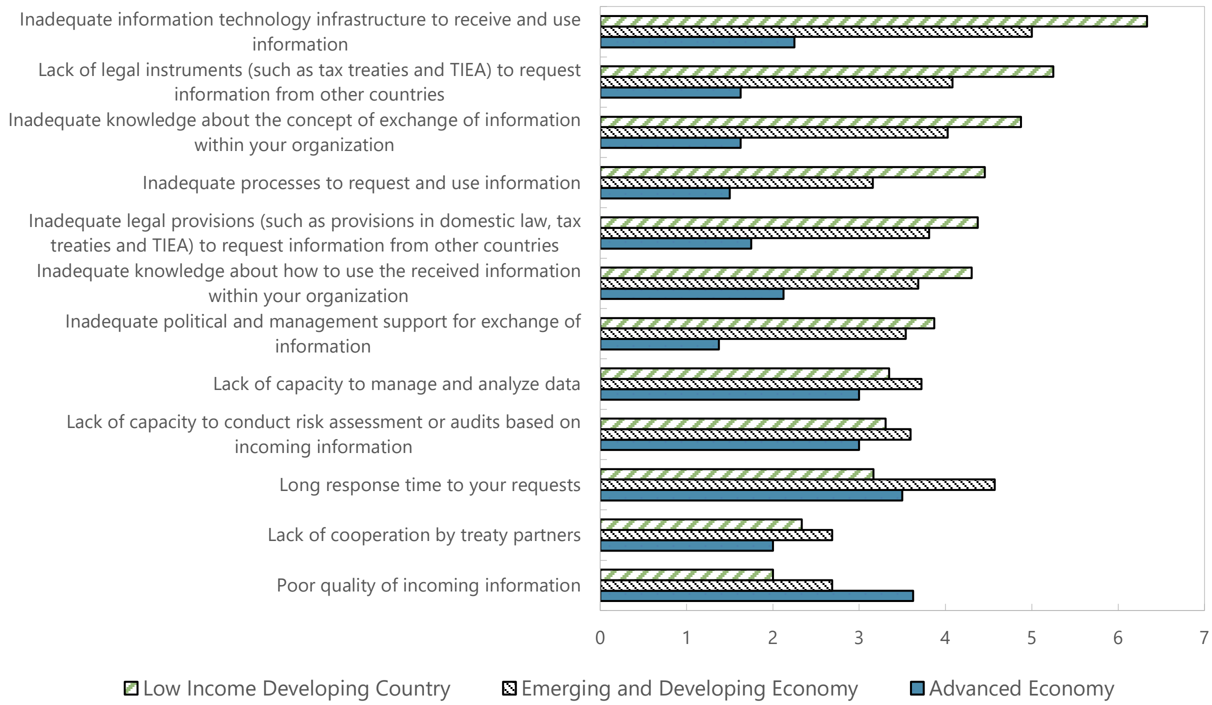
Opportunities Presented by International Tax Cooperation

Despite the challenges, countries can clearly see the benefits of ITC (Figure 2.3.5). Respondents were asked to rate, on a scale of 1 (not likely) to 10 (very likely) the opportunities presented by ITC. Both LIDCs and EMEs identified higher tax revenues, better relationships with foreign tax administrations, improved audit capabilities, and improved tax collection capabilities as key benefits. AEs reported the most significant

[10] Potential challenges include: (i) Lack of legal instruments (such as tax treaties and TIEA) to request information from other countries; (ii) Inadequate legal provisions (such as provisions in domestic law, tax treaties and TIEA) to request information from other countries; (iii) Inadequate knowledge about the concept of exchange of information within your organization; (iv) Inadequate knowledge about how to use the received information within your organization; (v) Inadequate political and management support for exchange of information; (vi) Inadequate information technology infrastructure to receive and use information; (vii) Inadequate processes to request and use information; (viii) Long response time to your requests; (ix) Lack of cooperation by treaty partners; (x) Poor quality of incoming information; (xi) Lack of capacity to conduct risk assessment or audits based on incoming information; (xii) Lack of capacity to manage and analyze data. The rating scale was a range from 1 for 'not a challenge' through to 10 for 'significant challenge".

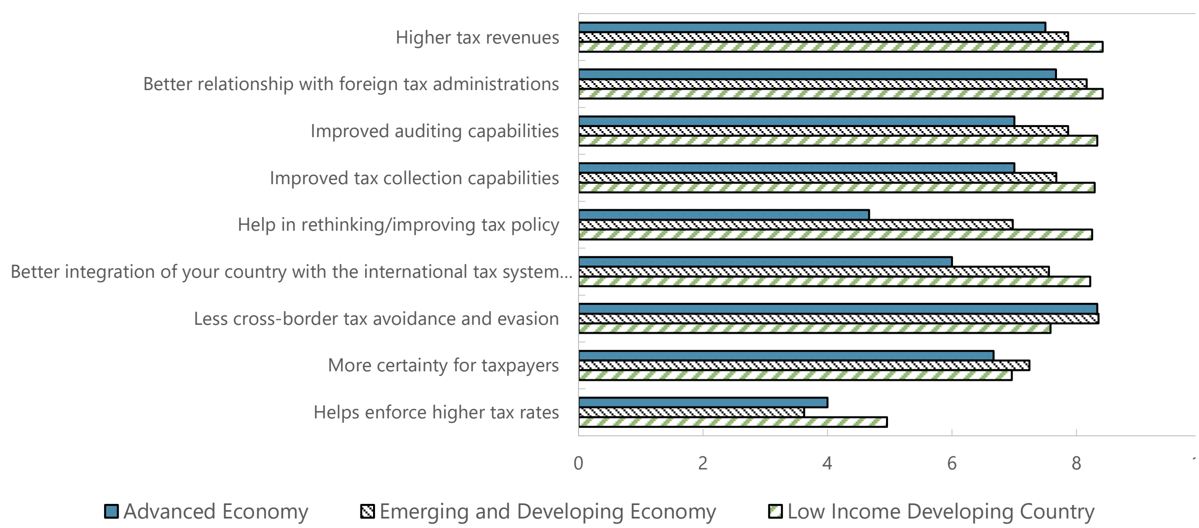
opportunities as reducing cross border tax avoidance and improved tax collection capabilities. Building on these positive views toward international tax collaboration, broader collaboration is expected to increase learning opportunities among peer administrations and further increase tax transparency and knowledge building internationally.

Online Annex Figure 2.3.4. Challenges in Using Exchanged Information



Source: Compiled by IMF staff based on a survey.

Online Annex Figure 2.3.5. Opportunities from ITC



Source: Compiled by IMF staff based on a survey.

Online Annex 2.4. Revenue Implications of Cross-Border Remote Work

This annex presents the empirical methodology to quantify the impact of cross-border remote work on personal income tax revenues (Figure 2.5 in Chapter 2). Prior to the pandemic, many countries with relatively low tax rates offered citizenship or residency to high-net-worth individuals. Since the onset of the pandemic, the number of countries offering 'digital nomad' visas, targeted at high-skilled individuals who can work remotely, has more than doubled from 16 to 40. These visas ease some of the frictions associated with cross border remote work, and for some jurisdictions, digital nomad visas explicitly exclude personal income tax liability in the residence jurisdiction. Some high tax jurisdictions offer special tax regimes for foreigners or returning expats, providing a lower effective personal income tax rate for a limited period through either lower statutory rates or a discount on taxable income.

Methodology

The approach is similar to De La Feria and Maffini (2021) who estimate the potential PIT revenue loss for the UK from increased teleworkability enabling high-income individuals to move abroad. The methodology is a two-step baseline specification that mimics the approach of general equilibrium models of international trade and migration (Walmsley, 2002). First, it measures the probability and magnitude of personal income tax base erosion for countries with average effective tax rates (AETRs) above the world average. Second, it distributes the total pool of teleworking personal income tax base "diverted" among countries with below average AETRs and suitable teleworking conditions.

The cross-border telework share of personal income tax (PIT) base of country *i* is estimated as:

$$teleworkable\ share\ of\ PIT\ base_i = \theta_i \cdot \rho \cdot PIT\ liability\ of\ higher\ rate\ taxpayers_i,$$

where:

- θ_i: is the country-specific share of jobs that can be done remotely. This is measured as the "teleworkability" index for the top quintile, where available, or the mean teleworkability for the country, or a teleworkability share based on that country's income level. The data is from the World Bank's (2020) cross-country analysis covering 107 countries, building on Dingel and Neiman (2020) and Brussevich and others (2020).
- ρ is the share of employers set up for cross-border telework (PWC, 2020). Together with θ_i, it refines the likelihood of workers leaving and entering that country (i.e., given information communication technology infrastructure capacity, which affects a country's probability as a source of and suitability as a destination for cross-border remote workers, keeping tax rates constant).
- The PIT liability of higher rate taxpayers is taken to be the share of PIT revenue collected from the top quintile of the income distribution in each country. For 18 countries, the actual PIT liability distributions have been used (augmenting the structural form of the estimates)[1], and next the exercise is extended to 124 countries using simulated income and tax distributions obtained from Vellutini and Benitez (2021). This tax liability is converted to the PIT base by dividing by each country's top statutory PIT rate.
- A country loses PIT base if its tax rate (τ_i) is above the average AETR ($\bar{\tau}$) in all other countries for the average wage earner in the global teleworker population (i.e., if $\tau_i - \bar{\tau} > 0$). In particular,

(1) $PIT\ revenue\ loss_i = \varepsilon \cdot \frac{(\tau_i - \bar{\tau})}{(1-\tau_i)} \cdot teleworkable\ share\ of\ PIT\ base_i$ if $\tau_i - \bar{\tau} > 0$

[1] Data on the distribution of PIT liability by taxable income are sourced from PIT returns, which are then aggregated and published by national tax administration agencies or statistics agencies. For most countries, the data reflects PIT returns for the 2018 or 2019.

(2) $PIT\ revenue\ gain_i = Likely\ share\ of\ net\ teleworker\ import_i \cdot aggregate\ pool\ of\ global\ PIT\ base\ in\ exodus \cdot \tau_i$ if $\tau_i - \bar{\tau} < 0$

where:

ε is a measure of the international mobility elasticity of high-income workers with respect to an AETR differential, taken to be one in this exercise based on the meta-analysis conducted by Stantcheva and others (2020). For the tax differential $(\tau_i - \bar{\tau})$, the average wage earner in the global teleworker population is assumed to be USD 75,000 in labor income per year (including allowances). The sensitivity analysis considers USD 100,000 and USD 200,000.[2]

- $Likely\ share\ of\ net\ teleworker\ import_i = \frac{(\tau_i - \bar{\tau})}{\sum_i^I (\tau_i - \bar{\tau})} \cdot \rho \cdot \theta_i$ is normalized to sum to 1.

- *The aggregate pool of global PIT base in exodus* is the total taxable personal income subject to "jurisdictional diversion" due to telework (i.e., the sum of personal income lost by countries with AETRs above average in (1)). Since the sample of 124 countries is smaller than the global population, an adjustment has been made for this estimated "lost pie" of taxable income for the missing share of world GDP.

*Caveat*s: The estimates ignore restrictions to international labor mobility (e.g., visa-related) and constraints imposed by possible double taxation of PIT income. For simplicity, labor mobility across borders is assumed to be frictionless, with an elasticity that solely responds to tax differentials in this setting.[3] In addition, the estimates capture only the taxation of salaries (without considering social security contributions or other sources of income). Incorporating capital income in the estimates (e.g., interest and dividends) would likely expand the size of revenue at stake given that many low-tax jurisdictions have favorable tax treatment of capital income, including as part of their preferential tax regime for foreigners. Similarly, the focus here is only on migration due to tax differentials, in practice individuals relocate for many non-tax reasons, which would have implications for tax revenue.

Results

While potential PIT revenue shift is significant for a handful of countries, the average loss is estimated to be less than 0.1 percent of GDP, whereas the average gain is 0.2 percent of GDP – since most high PIT rate countries also tend to be more advanced economies, with higher GDP per capita, the impact for "net exporting" countries is smaller than for the average "net importing" country in our sample (Figure 2.4.1).

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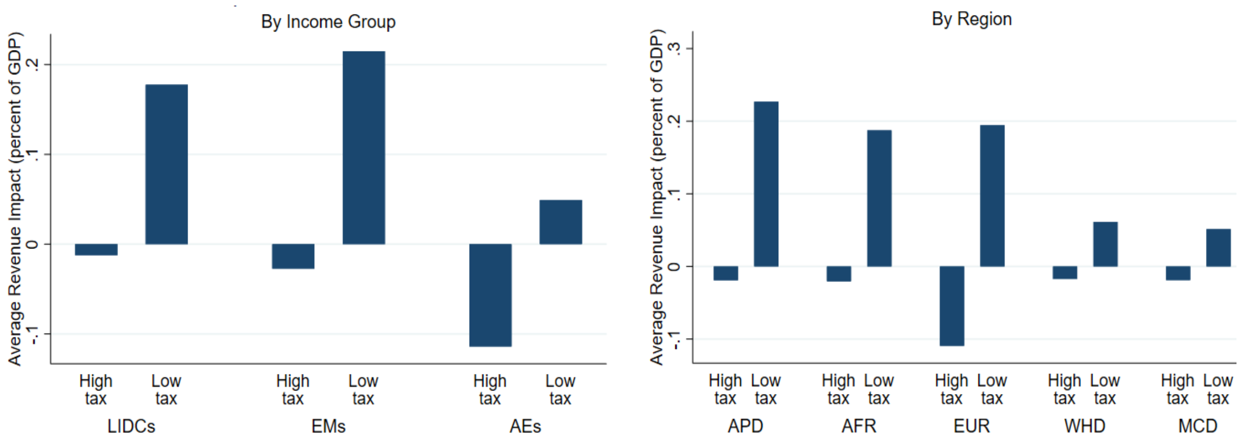
[2] The average wage in the top quintile, weighted by the teleworkability, share is US$68,414, while the average wage in the 95th percentile, weighted by teleworkability shares, is US$76,670. This is broadly in line with data on the average wage of the current pool of international remote workers of US$75,000 (e.g., Guiot, 2020, https://www.arthurguiot.com/remote-work-salary/ or ZipRecruiter (2021) https://www.ziprecruiter.com/Salaries/Telecommute-Salary). As a robustness exercise, we estimate the same set of equations by adjusting τ_i for special personal income incentive regimes, where applicable to foreign sourced income of US$75,000 per year: FRA, IDN, ISR, NZD, PRT to 0%; GRC to 0.5×ETR; ITA to 0.3×ETR; MLT to 15%; NLD to 0.7×ETR; PHL to 25%; SWE to 0.75×ETR; THA to 15%.

[3] The analysis is applicable mostly to the multinationals' setting, with local offices already established permitting individuals to move across countries without being subject to double taxation.

Online Annex Figure 2.4.1. PIT Revenue Impact of Tax Competition over Cross-Border Remote Work



Source: IMF staff estimates.

Small emerging economies, with below (but close to) average tax rates worldwide of 21 percent (for the representative remote worker) and high teleworkability indices are the typical winners in this zero-sum distribution. The overall base of taxable income at stake given current average effective tax rates and international teleworkability under conservative assumptions is estimated to be close to USD 40 billion. Considering special tax regimes in the effective tax rates used would cut this pool of potential losses by nearly half – suggesting they may be particularly attractive to relatively high tax countries. Nonetheless, increasing the average salary of the representative remote worker or the share of employers willing to offer international teleworkability options (and therefore the share of current high-income workers who may choose to move in this scenario) could considerably increase this figure. Table 2.4.1 shows sensitivity estimates for a range of alternative parameters and baseline assumptions. The estimated US$40 billion is only 1¼ percent of the relevant tax base for high tax countries in the sample. However, more liberal assumptions could raise that figure tenfold, without even considering incentives for international remote work unrelated to tax differentials, suggesting that the magnitude of the revenue pool under potential competition could be much larger.

Online Annex Table 2.4.1. Sensitivity Estimates of Global PIT Tax Base at Stake

Share of employers offering international teleworkability	Salary (USD)		
	75,000	100,000	200,000
	Estimated global base effect (USD billion)		
$\rho = 0.26$	40	58	114
$\rho = 1$	154	223	436

Source: IMF staff estimates.

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Online Annex 2.5. Emissions Equivalence of Other Mitigation Approaches to Carbon Pricing

To accommodate non-pricing and other approaches in an international carbon price agreement, recognition of the equivalence of such alternative approaches is needed. It is possible to assess the emissions reductions from other approaches (such as a regulation) and compare them with carbon-pricing, or to map these approaches to equivalent carbon prices, using a consistent framework applied to country-specific information on the sources of emissions and the responsiveness of emissions to prices. For example, if a country committed through a non-pricing measure that was deemed credibly to yield a given reduction in emissions, a methodology is available to compute the equivalent carbon price that would attain the same emissions reduction.

Instruments other than carbon-pricing do not promote the full range of mitigation opportunities—for example, within the transport sector a vehicle CO_2 per mile standard will promote sales of lower-emission vehicles but will not encourage people to drive less. In the power sector, an emission rate standard will promote switching among fuels to lower the emissions intensity of generation, but it will do little to exploit reductions in electricity demand as it does not involve the pass through of carbon-pricing revenues in higher electricity prices.

Moreover, taxes that apply only to a subset of energy products, for example, will have less comprehensive coverage and thus a lesser impact for a given tax rate. A tax on coal will reduce emissions from coal use but will not reduce emissions from oil products and natural gas. Even so, especially for countries that rely significantly on coal, the impact can be sizable, and can be computed using the same framework. In some cases, a variety of overlapping measures may be used to implement a sectoral target—for example, renewable generation tax credits, renewable portfolio standards, consumer tax credits, to promote renewable power generation, or building energy codes, incentives for clean heating equipment, appliance efficiency standards, insulation incentives to reduce energy use and CO_2 emissions from buildings. In these cases, it may be more practical to measure the carbon price equivalent of the sectoral clean energy or emissions targets rather than the effect of individual measures.

This Annex describes a methodology—based on the Climate Policy Assessment Tool (CPAT)—that provides consistent cross-country estimates of future emissions and that can be used to estimate the emissions impacts of various alternative mitigation instruments (Box 2.5.1).

For illustration, the first five columns in Table 2.5.1 show, using CPAT, the proportionate reductions in fossil fuel CO_2 emissions from tax policies applied to a narrower energy base relative to that of an economy-wide $75 carbon price by 2030. For transparency, policies are scaled such that they impose an explicit or implicit $75 per ton price on the emissions they cover (policies are gradually phased in from 2022-2030). The last column indicates emissions reductions if countries were to meet their pledges for renewable generation shares by 2030.

Some noteworthy points include:

- Coal taxes could achieve a substantial portion of the reductions in CO_2 compared with a carbon tax in large coal-consuming countries such as China, India, Indonesia, South Africa, and Germany. This is because the bulk of the CO_2 reductions under a comprehensive carbon tax in these countries would come from reduced use of coal given (i) the relatively high contribution of coal to CO_2 emissions in these countries and (ii) the much larger price increases for coal than for oil products and natural gas (due to the high carbon intensity of coal);
- Limiting carbon-pricing to the power and industry sectors results in emissions reductions that are typically around 50-80 percent of those under carbon-pricing;

- Taxes on electricity output (or consumption) can achieve about 10-30 percent of the emissions reductions from comprehensive carbon-pricing;
- Taxes on CO_2 emissions from power generation are significantly more effective at reducing emissions than taxes on electricity output as the former promotes fuel switching opportunities to lower the emissions intensity of generation as well as reductions in electricity demand;
- Road fuel taxes have limited mitigation potential, reducing CO_2 emissions by only around 5-20 percent of the reductions under comprehensive pricing as transportation emissions are a minor fraction of nationwide emissions and carbon-pricing causes only a relatively modest increase in retail fuel prices; and
- In many countries (especially where renewable targets are ambitious, and electricity is a sizeable portion of economywide emissions) achieving renewable energy pledges would achieve considerable emissions reductions (around 40 percent or more of those from a $75 carbon price in ten cases).

Online Annex Table 2.5.1. Proportionate CO_2 Reduction from Alternative Policies Relative to Comprehensive $75 Carbon Price, G20 Countries, 2030

Country	Coal tax	Carbon pricing for power/ industry	Electricity output tax	Electricity CO_2 tax	Road fuel taxes	Pledged renewables
Australia	0.80	0.85	0.36	0.44	0.03	n/a
Canada	0.28	0.41	0.03	0.34	0.06	0.60
France	0.41	0.22	0.00	0.56	0.33	0.14
Germany	0.72	0.58	0.08	0.50	0.18	1.04
Italy	0.40	0.46	0.10	0.46	0.23	0.26
Japan	0.72	0.68	0.26	0.47	0.02	0.32
Korea	0.84	0.72	0.21	0.55	0.01	0.42
United Kingdom	0.41	0.43	0.07	0.66	0.22	0.72
United States	0.52	0.70	0.23	0.36	0.05	0.03
Advanced econ. average	**0.57**	**0.56**	**0.15**	**0.48**	**0.13**	**0.44**
Argentina	0.04	0.47	0.17	0.27	0.03	n/a
Brazil	0.36	0.47	0.02	0.43	0.10	n/a
China	0.96	0.80	0.20	0.44	0.01	0.39
Mexico	0.20	0.61	0.31	0.40	0.09	0.68
Russia	0.39	0.46	0.14	0.24	0.01	n/a
Saudi Arabia	0.00	0.52	0.43	0.19	0.11	1.11
Turkey	0.76	0.65	0.17	0.59	0.02	n/a
High-inc. EME average	**0.39**	**0.57**	**0.21**	**0.37**	**0.05**	**0.73**
India	0.94	0.88	0.31	0.45	0.01	0.45
Indonesia	0.72	0.75	0.28	0.45	0.11	0.57
South Africa	0.97	0.74	0.27	0.17	0.01	0.46
Low-inc. EME average	**0.88**	**0.79**	**0.29**	**0.36**	**0.04**	**0.49**
G20 average	**0.55**	**0.60**	**0.19**	**0.42**	**0.09**	**0.51**

Source: IMF Staff analysis.
Note: The table shows proportionate reductions in fossil fuel CO_2 emissions from policies relative to that of an economy-wide $75 carbon price by 2030, gradually phased in by 2030 (1 = same reductions as a carbon tax). All policies (except pledged renewables) are scaled such that they impose an explicit or implicit $75 CO_2 price on the emissions sources they cover. The coal tax is a $75 CO_2 price applied to coal but not to oil products or natural gas (the tax per ton of coal varies moderately across countries with differences in the carbon intensity of coal). Electricity output taxes are charged per kwh, unrelated to carbon, but causing the same increase in electricity prices as a $75 carbon tax. Electricity CO_2 taxes are charged based on carbon content per kwh generated (this policy is equivalent to a carbon price restricted to fuels used in power generation). Road fuel taxes are increases in taxes on gasoline and diesel used in road transportation with taxes equal to CO_2 emissions per unit of fuel use times $75 per ton. Pledged renewables policy assumes implementation of countries' pledges on shares of renewables in power generation. n/a denotes non-binding targets.

One further complication is that, after countries have implemented carbon-pricing, they may change pre-existing energy taxes in a way that partially offsets, or enhances, the effectiveness of a formal carbon-pricing scheme. In this case, it can make sense to track a country's 'effective carbon price', which takes account of energy taxes, as well as the possibility that formal carbon-pricing does not have complete coverage. The effective carbon price can be computed, using a CPAT type model, by estimating: (i) the increase in emissions that would result if formal carbon-pricing and energy taxes were removed; and (ii) the comprehensive carbon price that would reduce emissions back to their initial level.

There is little basis on economic efficiency grounds for equating effective carbon prices since these vary considerably across countries, and there are many other externalities beyond climate change (Parry and others 2021). Instead, countries might be required to increase their effective carbon price relative to its absolute value in a benchmark year. This would allow countries flexibility in meeting the requirement (e.g., through extending coverage of emissions pricing, raising preexisting fuel excises) but prevent relabeling of fuel taxes imposed for other reasons as carbon taxes. Benchmark prices might be defined excluding explicit carbon-pricing schemes to avoid penalizing those who have already acted.

Online Annex Box 2.5.1. Climate Policy Assessment Tool (CPAT) and its Parameterization

CPAT provides, among other metrics, projections of fuel use and CO_2 emissions by major energy sector—power generation, industry, transport, and buildings for over 200 countries. The tool observes recent fuel use and projects forward using: GDP projections; assumptions about the income elasticity of demand and price responsiveness of fuel use in different sectors; rates of technological change that affects energy efficiency of different energy sources; and future international energy prices. In these baseline projections, current carbon-pricing, non-pricing policies, and fuel taxes are (explicitly or implicitly) held fixed at their 2021 levels of stringency.

The impact of carbon-pricing on fuel use and emissions depends on: (i) the proportionate impact on future fuel prices in different sectors; and (ii) the price responsiveness of fuel use in different sectors. Proportionate fuel price increases depend on baseline prices, carbon emissions factors for fuels, and the pass through of carbon charges into fuel user prices.

In the power sector, fuel price responsiveness is determined by a model of dispatch and new investment in alternative generation technologies. In the residential sector, fuel and electricity demand are decomposed into responses reflecting changes in energy efficiency (e.g., insulation upgrades and adoption of energy efficient appliances in buildings) and behavioral changes (e.g., economizing on use of lighting, heating). The industrial sector is disaggregated into ten industries (e.g., iron and steel, machinery, cement). In each industry carbon-pricing reduces the emissions intensity of production (though adoption of cleaner or more energy efficient technologies) and reduces production levels as carbon charges are reflected in higher consumer prices. In the vehicle sector, fuel consumption from gasoline and diesel vehicles declines in response to higher prices as individuals switch to more fuel-efficient and zero emission vehicles and reduce vehicle miles travelled. Capital turns over gradually (explicitly in the power sector and implicitly in other sectors through fuel price elasticities that are more responsive in the longer term) so the full effect of policy changes occurs progressively over time.

CPAT is populated using data compiled from the International Energy Agency (IEA) on recent fuel use by country and sector. GDP projections are from the latest IMF forecasts. Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources. International prices for coal, oil, and natural gas (at the global level for oil and regional level for coal and gas) are projected forward using an average of IEA (which are rising) and IMF (which are flat) projections. Domestic energy prices are projected using empirical estimates of the pass-through of changes in international energy prices into domestic fuel prices by country. Fuel and electricity price responsiveness is parameterized to be broadly consistent with empirical evidence and results from energy models (fuel and electricity price elasticities are typically between about -0.5 and -0.8). CO_2 and other GHG emissions factors by fuel product are from the International Institute for Applied Systems Analysis.

One caveat is that, while the assumed fuel price responses are plausible for modest fuel price changes, they may not be for larger price changes that might ultimately drive non-linear adoption of technologies whose future viability and costs are highly uncertain at present, like carbon capture and storage (that could be deployed in the power and industry sectors) and direct air capture.[1] We therefore assume a backstop technology that can be deployed at a constant unit cost of $125 per ton of CO_2 reduced. In addition, fuel price responsiveness is approximately similar across countries—in practice, price responsiveness may differ across countries with the structure of the energy system and regulations on energy efficiency and emission rates. CPAT does not distinguish heterogeneity at the firm level in the power generation and industrial sectors—this distinction does not matter for our purposes however if behavioral responses at the industry level are appropriately parameterized. CPAT does not explicitly account for the) impact on trade or changes in international fuel prices that might result from simultaneous climate or energy price reform in large countries. The model is parameterized, however, such that emissions projections and the price responsiveness of fuel use and CO_2 emissions is broadly consistent with that from far more detailed energy and computable general equilibrium models that, to varying degrees, account for these sorts of factors.

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[1] In practice, scaling carbon capture and storage technologies has proven extremely difficult, hampered by fluctuating policy and financial support, in addition to difficult site-specific technical hurdles (Global CCS Institute 2021).