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Data Flow and Economic Value EU Framework:

Modelling Update and Data Collection

FINAL STUDY REPORT

frontier economics

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ABSTRACT

This study aims to deliver one of the key actions of the EU Data Strategy: *the creation of a framework to measure data flows and estimate their economic value within Europe, as well as between Europe and the rest of the world*. The study focuses on data flows triggered by enterprises that use cloud services in the EU, EFTA and the UK (enterprise cloud-based data flows – ECBDFs). It provides an update of existing methodologies to estimate both the volume and destination of ECBDFs. A novel analytical framework to estimate the economic value of ECBDFs based on microeconomic principles is also developed.

The study estimates that, in 2024, the EU will generate around 46,000 petabytes (PB) of ECBDFs. This volume will increase to around 5,560,000 PB by 2035. Of the 46,000 PB generated in 2024, 36,600 PB are expected to flow to cloud and edge facilities within the EU, 1,950 to EFTA and the UK, and 7,345 PB to other regions (Africa, America, Middle East and Asia). The estimated economic value of ECBDFs in the EU in 2024 is €77bn, estimated to increase to €328bn by 2035.

ABSTRAIT

Cette étude met en œuvre l'une des actions de la stratégie de l'UE en matière de données : *la création d'un cadre permettant de mesurer les flux de données et d'estimer leur valeur économique en Europe, et entre l'Europe et d'autres régions*. L'étude se concentre sur les flux de données déclenchés par les entreprises utilisant des services cloud dans l'UE, l'AELE et le Royaume-Uni (« flux de données cloud »). Elle met à jour une méthodologie afin d'estimer le volume et la destination des flux de données cloud. Elle développe également un cadre analytique pour estimer la valeur économique des flux de données cloud sur base de principes microéconomiques.

L'étude estime qu'en 2024, l'UE produira ~46 000 pétaoctets (PB) de flux de données cloud. Ce volume passera à ~5 560 000 PB d'ici 2035. Sur les 46 000 PB générés en 2024, 36 600 PB devraient être acheminés vers des centres de données cloud et edge au sein de l'UE, 1 950 vers l'AELE et le Royaume-Uni, et 7 345 PB vers d'autres régions (Afrique, Amérique, Moyen-Orient et Asie). La valeur économique estimée des flux de données cloud dans l'UE en 2024 est de 77 milliards d'euros et devrait atteindre 328 milliards d'euros en 2035.

EXECUTIVE SUMMARY

This report presents the results of the “Data Flow and Economic Value EU Framework: Modelling Update and Data Collection” study (CNECT/2021/OP/0046), commissioned by the European Commission, Directorate-General for Communications Networks, Content and Technology (DG CNECT), and undertaken by Frontier Economics.

This report focuses on data flows triggered by enterprises that use cloud services (including edge computing) and that are located in the EU, EFTA and the UK. It estimates the volume, the origin, the destination and the economic value of these enterprise cloud-based data flows (ECBDFs) from 2016 to 2036, using exclusively secondary data and statistics. The estimates are based on an enhanced analytical framework for geographically mapping ECBDFs which builds on previous studies commissioned by DG CNECT[1] and on a novel framework for measuring the economic value of ECBDFs developed specifically for this study.

This report, along with the accompanying methodological note and online visualisation tool, aims to deliver on one of the key actions of the EU Data Strategy,[2] and to inform the EU’s industrial strategy and digital and data policies at large. This includes: the assessment of two of the EU’s Digital Decade targets (the percentage of enterprises using cloud services, and the number of edge nodes deployed); and the upcoming evaluation of the EU Regulation (2018/1807) on the Free Flow of Non-Personal Data. The analytical framework and economic modelling could also support future decisions on investment in cloud and edge computing capabilities and the governance of international data flows.

The total volume and value of ECBDFs in Europe (EU, EFTA and the UK)

The report estimates that, in 2024, enterprises that operate in the EU and use cloud services will generate approximately **46,000 petabytes/year (PB/year) of ECBDFs**. This is around 300 times the data storage capacity of the Internet Archive, the world’s largest library of internet content, which archives over 860 million web pages.[3]

In EFTA countries (Iceland, Liechtenstein, Norway and Switzerland), enterprises will generate **1,725 PB/year of ECBDFs in 2024**, and enterprises in the **UK will generate 16,500 PB of ECBDFs** in the same year. In total across Europe, it is expected that European enterprises will generate just over **64,000 PB/year of ECBDFs in 2024.**

These ECBDFs have great economic significance: in 2024 the economic value of European ECBDFs is estimated to be €107bn, of which €77bn is in EU, €8bn in EFTA countries and €22bn in the UK. To put this into context, the European total value of ECBDFs is greater than the gross domestic product (GDP) of Bulgaria (and than the GDP of several other European countries including, for example, Croatia, Estonia, Latvia, and Lithuania). The economic value of ECBDFs in the EU in 2024 includes:

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1 A study published in 2021 and produced by Valdani Vicari & Associates (hereafter the “VVA report” or “VVA study”), which focused only on the volume and location of ECBDFs, and a later study published in 2023 (hereafter “Ipsos/Tech4i2 report”), which also estimated the economic value of ECBDFs.

2 The creation of a framework to measure data flows and estimate their economic value within Europe, as well as between Europe and the rest of the world.

3 As of 10 January 2024. Source: https://archive.org/~tracey/mrtg/du.htmlhttps://archive.org/~tracey/mrtg/du.html, retrieved on 10/1/2024 at 10.36 CET.

- About **€95.7bn of** additional gross value added (GVA) generated by European enterprises that use cloud services, as a result of ECBDFs **(demand-side value)**;
- About **€11bn of** profits realised by cloud service providers in Europe, attributable to the role of ECBDFs **(supply-side value)**;
- Around **€0.3bn** of wider net economic value (externalities), including €0.5bn value of job creation linked to ECBDFs and a negative €0.2bn value representing the environmental cost of greenhouse gas (GHG) emissions linked to ECBDFs. A large majority of both jobs (over 99%) and emissions (over 80%) is generated by cloud data centres in the country of destination of ECBDFs. The remaining value (less than 1% of jobs and 20% of emissions) is linked to the installation, operation and maintenance of connecting infrastructure in the country of destinaton (i.e. through cables, exchange stations, servers and switches).

Both volume and value of ECBDFs are expected to increase significantly over time:

- The **volume** of ECBDFs that originate from the EU is expected to reach 5.6m PB/year in 2035, **an increase of approximately 120 times from 2024**.
- The **value** of ECBDFs that originate from EU countries is expected to increase to €328bn in 2035**, an increase by a factor of 4.3 compared to 2024.**

As shown in Table 1 below, the value of local job creation and the cost of GHG emissions resulting from EU ECBDFs are expected to increase by a factor of 100 and a factor of 30 respectively – much faster than the demand-side value and supply-side value of ECBDFs. This is because, compared to demand-side and supply-side value, the values of local job creation and GHG emissions are more closely linked with the volume of ECBDFs.

The volume and value of ECBDFs in EFTA, the UK and Europe as a whole are also estimated to increase by similar orders of magnitude.

Table 1 Volume and value of ECBDFs in the EU, 2024-2035

	2024	2025	2030	2035
Volume of ECBDFs (PB)	**45,893**	**70,300**	**588,926**	**5,559,233**
Demand-side value (€m)	69,178	80,349	147,219	239,275
Supply-side value (€m)	7,860	9,589	22,875	44,027
Value of local job creation (€m)	484	741	5,909	50,742
Value of GHG emissions (€m)	-208	-295	-1,524	-5,869
Total value of ECBDFs (€m)	**77,314**	**90,384**	**174,478**	**328,175**

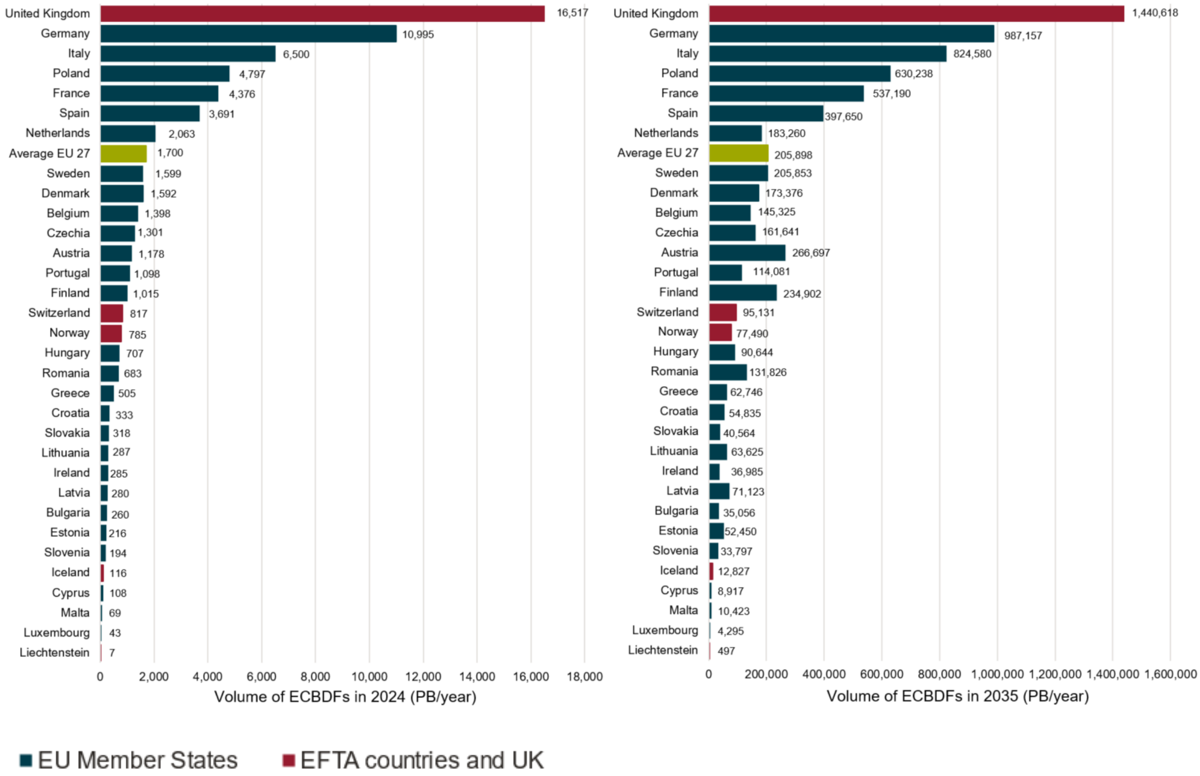
Volume and value of ECBDFs by country

As shown on the left side of Figure 1 below, **the five European countries that are expected to generate the most ECBDFs in 2024 are the UK, Germany, Italy, Poland and France**. In total, these five countries account for two-thirds of the total volume of ECBDFs that originate from European enterprises. This is primarily due to the number of enterprises that use cloud services and the number of workers employed by these enterprises. Conversely, smaller countries such as Liechtenstein, Iceland, Luxembourg, Malta and Cyprus are estimated to have generated as a group around 0.5% of all European ECBDFs in 2023. This is explained by the smaller size of these countries' economies.[4] The top five and bottom five countries in

[4] Indeed, the volume of ECBDFs generated in four of these five countries (Iceland, Luxembourg, Malta and Cyprus) relative to the size of their economy (measured by GVA) is in line with the European average. The ratio of ECBDFs generated to GVA in Liechtenstein is lower than the European average, due to the low uptake

Europe in terms of ECBDF volumes are expected to remain the same in future years, including 2035, as shown on the right side of the figure.

Figure 1 ECBDFs generated by each European country (i.e. country of origin of the flows) in 2024 and 2035



The overall size of an economy also influences the value of ECBDFs for that country, as shown in Figure 2 below. However, our results show that **the economic value of ECBDFs is not linearly related to the volume of ECBDFs**.[5] This is because the value of ECBDFs is greater when they are more “critical”: in other words, where constraining ECBDFs would be particularly detrimental for the enterprises that use and provide cloud services. Indeed, as shown in the figure, **Ireland, Finland, Netherlands and Sweden all rank significantly higher in terms of the value of ECBDFs that they generate, compared to volume**. The criticality of ECBDFs is particularly high in these countries, which explains why the value of ECBDFs for Ireland, Finland, Netherlands and Sweden is high relative to the volume of ECBDFs that they generate.

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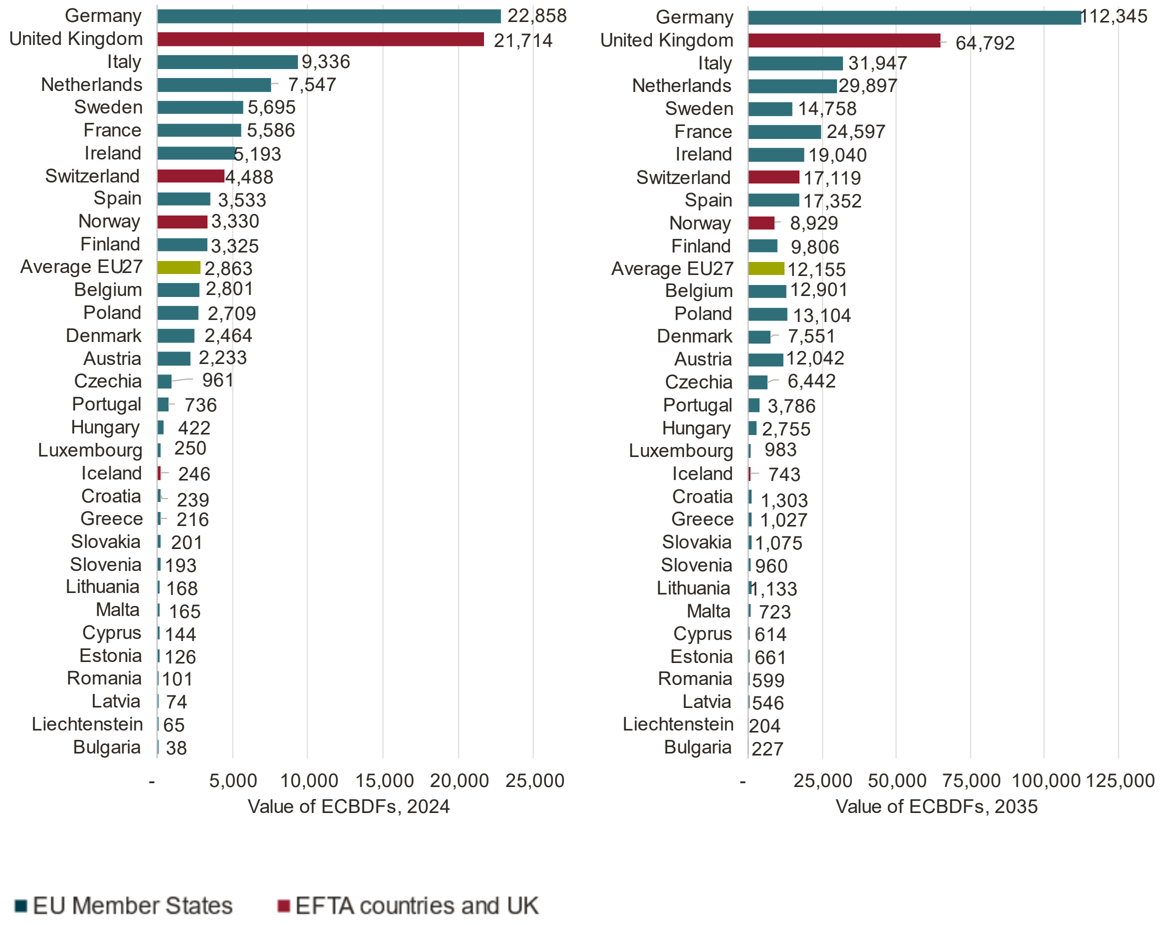
of cloud services in the country; however, even if this ratio was the same as the European average, Liechtenstein would still rank in the bottom five in terms of ECBDFs generated.

5 In other words, if one country generates 1EX/month of ECBDFs and another country generates 5EX/month, it is not necessarily the case that the second country can extract five times more value from ECBDFs compared to the first one.

Figure 2 The economic value of ECBDFs in 2024 by country, €m



As in the case of volume, the distribution of value of ECBDFs between European countries is also expected to remain broadly similar over time. As shown in Figure 2 above, the bottom five countries in terms of the value of ECBDFs in 2035 are expected to be the same as in 2024. The picture at the top of the 2024 and 2035 charts is also broadly similar, although the value of ECBDFs in France, Ireland, Spain and Switzerland is expected to overtake the value of ECBDFs in Sweden, due to faster growth in the uptake of cloud services.

This study also estimates how the volume of ECBDFs and the value of these ECBDFs to enterprises that use cloud services vary by sector and firm size. We report below figures for the EU for brevity, but the picture is very similar for EFTA and the UK.

Volume and value of ECBDFs in the EU by sector and firm size

As shown in Figure 3 below, the three sectors that are expected to generate the largest magnitudes of ECBDFs in 2024 are: manufacturing (NACE code C, 7,600 PB/year), wholesale and retail (NACE code G, 6,400 PB/year), and human health & social work activities (NACE code Q, 5,300 PB/year). This is because they are the sectors with the highest number of workers (on average) across Europe (EU + EFTA + UK) and because cloud usage in these sectors is relatively high.[6] Conversely, the smallest sectors in terms of ECBDF generation are electricity (D), water supply (E), real estate (L), and arts (R).

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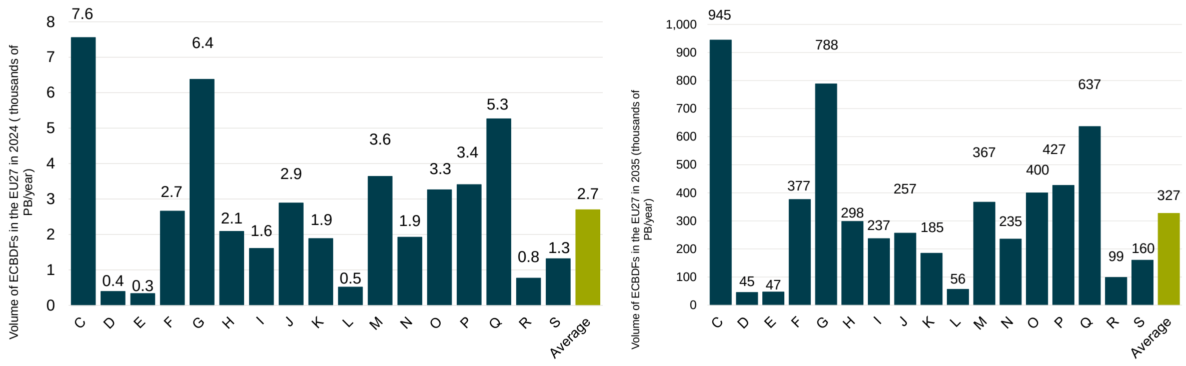
[6] The analysis of the volume and value of ECBDFs by sector does not include NACE sectors A (agriculture, forestry and fishing) and B (mining and quarrying). This is because data on cloud uptake and other indicators required to estimate the value of ECBDFs that originate from these sectors is not available.

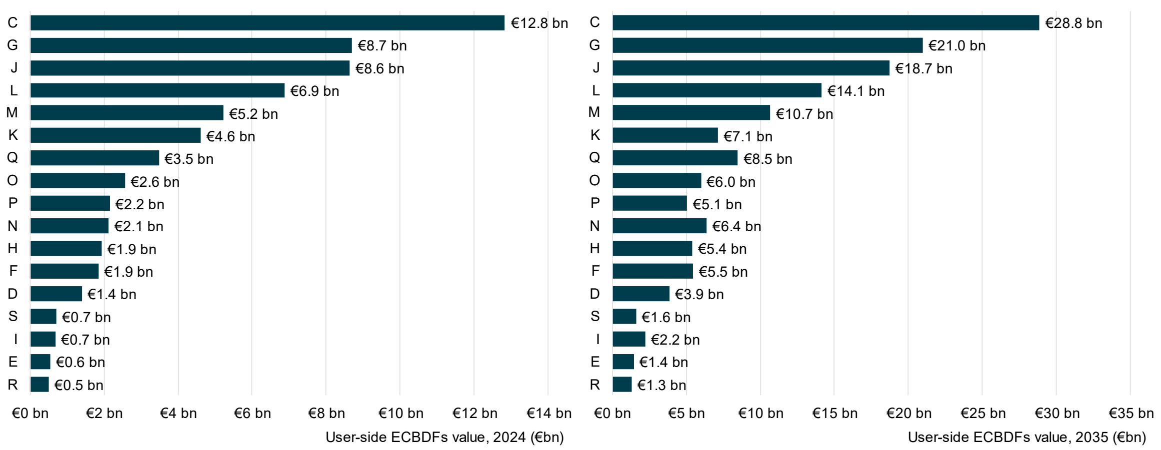
Figure 3 Volume of ECBDFs in the EU by NACE sector code (thousand PB/year), 2024 and 2035



Note: C=Manufacturing; D=Electricity, Gas, Steam and Air Conditioning Supply; E=Water Supply; Sewerage, Waste Management and Remediation Activities; F=Construction; G=Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H=Transportation and Storage; I=Accommodation and Food Service Activities; J=Information and Communication; K=Financial and Insurance Activities; L=Real Estate Activities; M=Professional, Scientific and Technical Activities; N=Administrative and Support Service Activities; O=Public Administration and Defence; Compulsory Social Security; P=Education; Q=Human Health and Social Work Activities; R=Arts, Entertainment and Recreation; S=Other Service Activities.

Consistent with the country-level results shown previously, a higher volume of ECBDFs does not necessarily translate into higher value. This difference in distribution between volume and value is again driven by the criticality of ECBDFs to sector usages of cloud computing services as measured by the Data Flows Criticality Index (DFCI) index. Our estimates indicate that the criticality of ECBDFs is higher in the information and communication, real estate and professional services sectors, compared to health & social care and other sectors.[7]

Figure 4 Demand-side (user) value of EU ECBDFs in 2024 and 2035, by sector (NACE codes C to S)



Note: sector codes as in Figure 3.

The demand-side value of ECBDFs to EU cloud-using enterprises in 2024 (€69.2bn) is split roughly equally between small and medium enterprises (SMEs) (€34bn) and large enterprises (€35.1bn). However, when we add in the value of ECBDFs to cloud providers, which are almost exclusively large businesses, we find that large enterprises account for around 56% of the

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7 In the case of real estate, the relatively high value of ECBDFs relative to their volume is also likely to be explained in part by the high capital intensity of this sector. High capital intensity means that there are relatively few workers in this sector compared to others, which means that lower ECBDFs are generated. However, the data relates to large amounts of assets and therefore is linked with high GVA.

value of ECBDFs to enterprises generated in Europe, with the remaining 44% generated by SMEs.

Our forecasts indicate that the distribution of ECBDF volume and value between sectors and firm sizes is likely to remain very similar over time.

Current and future patterns in intra- and extra-EU ECBDFs

This study estimates that in 2024, just over **57% (26,300 PB/year of ECBDFs)** of the 46,000 PB/year of ECBDFs generated by enterprises that operate in the EU and use cloud services **stayed within their origin countries, around one-fifth (10,000 PB/year) flowed to other European countries and around one-sixth (7,100 PB/year) flowed to non-European countries.**

The proportion of ECBDFs that stay within Europe is expected to increase over time, from 84% in 2024 to 90% in 2035. This is because an increasing proportion of ECBDFs is expected to be directed to edge data centres, and we model all ECBDFs that flow to edge data centres as staying within Europe (flowing to the nearest data centre).

There is significant value at stake from extra-EU ECBDFs. Indeed, in 2024, around €15.6bn of demand-side value (user value) of ECBDFs from EU enterprises involved cloud data flows from EU Member States to other countries, of which:

- **€3.2bn** was based on cloud data flows from the EU to EFTA countries;
- **€0.6bn** was based on ECBDFs from the EU to the UK; and
- **€11.8bn** was based on cloud data flows from the EU to other regions including America (€2.6bn), the Middle East (€4.3bn), Africa (€1.9bn) and South and East Asia (€3bn).

RÉSUMÉ EXÉCUTIF

Ce rapport présente les résultats de l'étude "Cadre Analytique de Quantification des Flux de Données Cloud et de leur Valeur Économique" (CNECT/2021/OP/0046), commanditée par la Commission européenne, Direction générale des réseaux de communication, du contenu et des technologies (DG CNECT), et réalisé par Frontier Economics.

Ce rapport se concentre sur les flux de données en provenance des entreprises utilisatrices de services d'informatique en nuage (ou services « cloud », y compris « edge ») au sein de l'UE, l'AELE et le Royaume-Uni. Il estime le volume, l'origine, la destination et la valeur économique de ces flux de données d'entreprise basés sur le cloud (« flux de données cloud ») de 2016 à 2036, en utilisant exclusivement des données et statistiques secondaires. Les estimations sont basées d'une part, sur un cadre analytique afin de réaliser une cartographie géographique des flux de données cloud qui s'appuie sur des études antérieures commanditées par la DG CNECT[8] . D'autre part, sur un nouveau modèle de quantification de la valeur économique des flux de données cloud développé spécifiquement pour cette étude.

Ce rapport, ainsi que la note méthodologique et l'outil de visualisation en ligne qui l'accompagnent, visent à concrétiser l'une des actions clés de la stratégie de l'UE en matière de données[9], à informer la stratégie industrielle de l'UE et les politiques en matière de numérique et de données au sens large. Cela comprend notamment le suivi de deux des objectifs de la décennie numérique de l'UE (le pourcentage d'entreprises utilisant des services « cloud » et le nombre de nœuds périphériques déployés) ; et l'évaluation à venir du règlement de l'UE (2018/1807) relatif à la libre circulation des données à charactère non personnel. Le cadre analytique et la modélisation économique pourraient également soutenir les décisions futures d'investissement dans les services et infrastructures cloud et edge computing et informer les débats relatifs à la gouvernance des flux de données internationaux.

Volume et valeur des flux de données cloud en Europe (UE, AELE et Royaume-Uni)

Le rapport estime qu'en 2024, les entreprises qui opèrent dans l'UE et utilisent des services cloud généreront environ **46 000 pétaoctets/an (PB/an) de flux de données cloud**. Cela représente environ 300 fois la capacité de stockage de données de l'Internet Archive, la plus grande bibliothèque de contenu internet au monde, qui archive plus de 860 millions de pages web[10].

Dans les pays de l'AELE (Islande, Liechtenstein, Norvège et Suisse), les entreprises généreront **1 725 PB/an de flux de données cloud en 2024**. Les entreprises du **Royaume-Uni généreront 16 500 PB de flux de données cloud** la même année. Au total, les entreprises européennes devraient générer un peu plus de **64 000 PB/an de flux de données cloud en 2024.**

8 Une étude publiée en 2021 et produite par Valdani Vicari & Associates (ci-après le "rapport VVA" ou "l'étude VVA"), qui se concentrait uniquement sur le volume et la localisation des flux de données, et une étude ultérieure publiée en 2023 (ci-après le "rapport Ipsos/Tech4i2"), qui estimait également la valeur économique de ces flux.

9 La création d'un cadre pour mesurer les flux de données et estimer leur valeur économique au sein de l'Europe, ainsi qu'entre l'Europe et le reste du monde.

10 En date du 10 janvier 2024. Source : https://archive.org/~tracey/mrtg/du.htmlhttps://archive.org/~tracey/mrtg/du.html, consultée le 10/1/2024 à 10.36 CET.

Ces flux de données cloud ont une grande importance économique : **en 2024, la valeur économique des flux de données cloud en Europe est estimée à 107 milliards d'euros, dont 77 milliards d'euros dans l'UE**, 8 milliards dans les pays de l'AELE et 22 milliards au Royaume-Uni. Pour replacer ce chiffre dans son contexte, la valeur totale des flux de données cloud en Europe est supérieure au produit intérieur brut (PIB) de la Bulgarie (et au PIB de plusieurs autres pays européens, notamment de ceux de la Croatie, l'Estonie, la Lettonie et la Lituanie). La valeur économique des flux de données cloud dans l'UE en 2024 comprend :

- Environ **95,7 milliards d'euros** de valeur ajoutée brute (VAB) générée par les entreprises européennes qui utilisent des services en nuage, grâce aux flux de données cloud **(valeur économique estimée du côté de la demande)** ;
- Environ **11 milliards d'euros** de bénéfices réalisés par les fournisseurs de services cloud en Europe, attribuables au rôle des flux de données cloud **(valeur économique estimée du côté de l'offre)** ;
- Environ **0,3 milliard d'euros** de valeur économique nette dûes aux externalités, comprenant 0,5 milliard d'euros de valeur économique relative à la création d'emplois liée aux flux de données cloud et une valeur négative de 0,2 milliard d'euros représentant le coût environnemental des émissions de gaz à effet de serre (GES) liées aux flux de données cloud. Une grande majorité des emplois (plus de 99 %) et des émissions (plus de 80 %) sont générés par les centres de données cloud dans les pays de destination des flux de données cloud. La valeur restante (moins de 1 % des emplois et 20 % des émissions) est liée à l'installation, l'exploitation et la maintenance de l'infrastructure de réseaux dans le pays de destination (c'est-à-dire par le biais de câbles, de stations d'échange, de serveurs et de commutateurs réseau).

Le volume et la valeur des flux de données cloud devraient augmenter de manière significative au fil du temps :

- Le **volume** des flux de données cloud originaires de l'UE devrait atteindre 5,6 milliards d'euros par an en 2035, **soit une augmentation d'environ 120 fois par rapport à 2024**.
- La **valeur** des flux de données cloud originaires des pays de l'UE devrait atteindre 328 milliards d'euros en 2035**, soit une augmentation d'un facteur de 4,3 par rapport à 2024**.

Comme le montre le tableau 1 ci-dessous, la valeur de la création d’emplois locaux et le coût des émissions de gaz à effet de serre résultant des flux de données cloud dans l'UE devraient augmenter respectivement d'un facteur 100 et d'un facteur 30, soit beaucoup plus rapidement que les valeurs économiques escomptées du côté de la demande et de l'offre générées par les flux de données cloud. En effet, par rapport aux valeurs escomptées du côté de la demande et de l'offre, les valeurs de la création d’emplois locaux et des émissions de gaz à effet de serre sont plus étroitement liées au volume des flux de données cloud.Le volume et la valeur des flux de données cloud dans l'AELE, au Royaume-Uni et dans l'ensemble de l'Europe devraient également augmenter dans des proportions similaires à celles de l’UE.

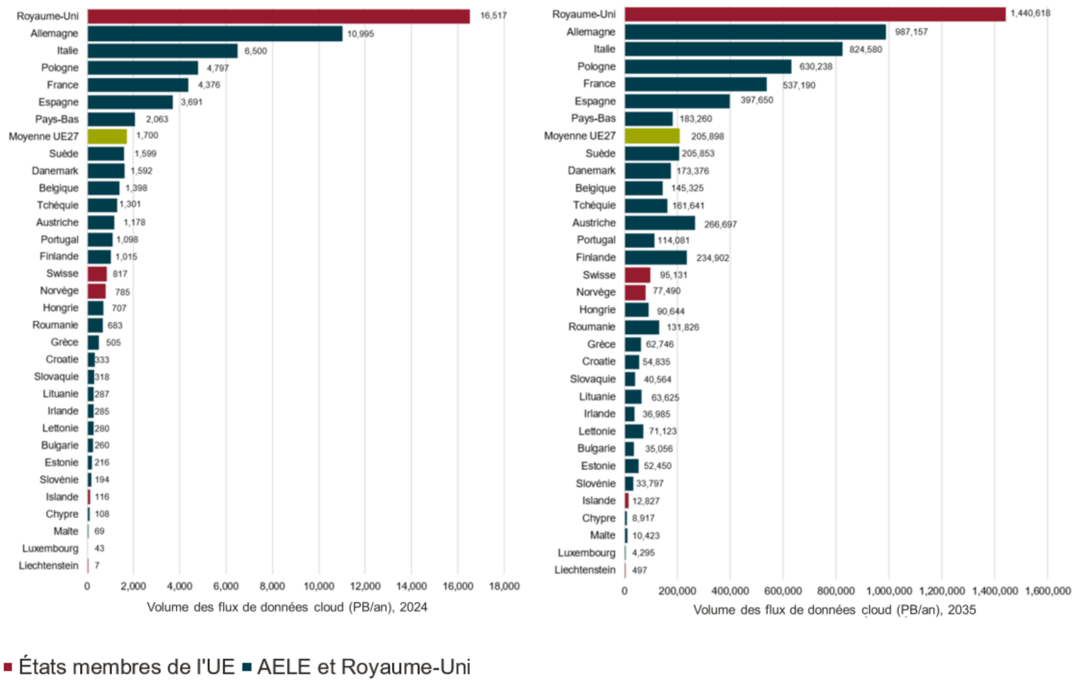
Tableau 2 Volume et valeur des flux de données cloud dans l'UE, 2024-2035

	2024	2025	2030	2035
Volume des flux de données cloud (PB)	**45 893**	**70 300**	**588 926**	**5 559 233**
Valeur de la demande (millions d'euros)	69 178	80 349	147 219	239 275
Valeur de l'offre (millions d'euros)	7 860	9 589	22 875	44 027
Valeur de la création d'emplois locaux (millions d'euros)	484	741	5 909	50 742
Valeur des émissions de GES (millions d'euros)	-208	-295	-1 524	-5 869
Valeur totale des flux de données cloud (millions d'euros)	**77 314**	**90 384**	**174 478**	**328 175**

Volume et valeur des flux de données cloud par pays

Comme le montre la partie gauche de la figure 1 ci-dessous, les **cinq pays européens qui devraient générer le plus de flux de données cloud en 2024 sont le Royaume-Uni, l'Allemagne, l'Italie, la Pologne et la France**. Au total, ces cinq pays représentent les deux tiers du volume total des flux de données cloud provenant des entreprises européennes. Cela s'explique principalement par le nombre d'entreprises qui utilisent des services cloud et le nombre de travailleurs employés par ces entreprises. À l'inverse, les petits pays tels que le Liechtenstein, l'Islande, le Luxembourg, Malte et Chypre sont estimés avoir généré, en tant que groupe, environ 0,5 % de tous les flux de données cloud européens en 2024. Cela s'explique par la taille plus réduite de l'économie nationale de chacun de ces pays[11]. Les cinq premiers et les cinq derniers pays d'Europe en termes de volume de flux de données cloud devraient rester inchangés dans les années à venir, y compris en 2035, comme le montre la partie droite de la figure 1.

Figure 5 Flux de données cloud générés par pays européen (i.e. pays d'origine des flux) en 2024 et 2035



La taille de l'économie nationale influence également la valeur économique des flux de données cloud pour ce pays, comme le montre la figure 2 ci-dessous. Toutefois, nos résultats montrent que la **valeur économique des flux de données cloud n'est pas linéairement corrélée au volume des flux de données cloud**[12]. En effet, la valeur des flux de données cloud est plus élevée lorsque ces derniers sont plus "critiques" : en d'autres termes, lorsque les flux de données cloud sont limités ceci serait particulièrement préjudiciable pour les entreprises qui utilisent et fournissent des services cloud. En effet, comme le montre la figure

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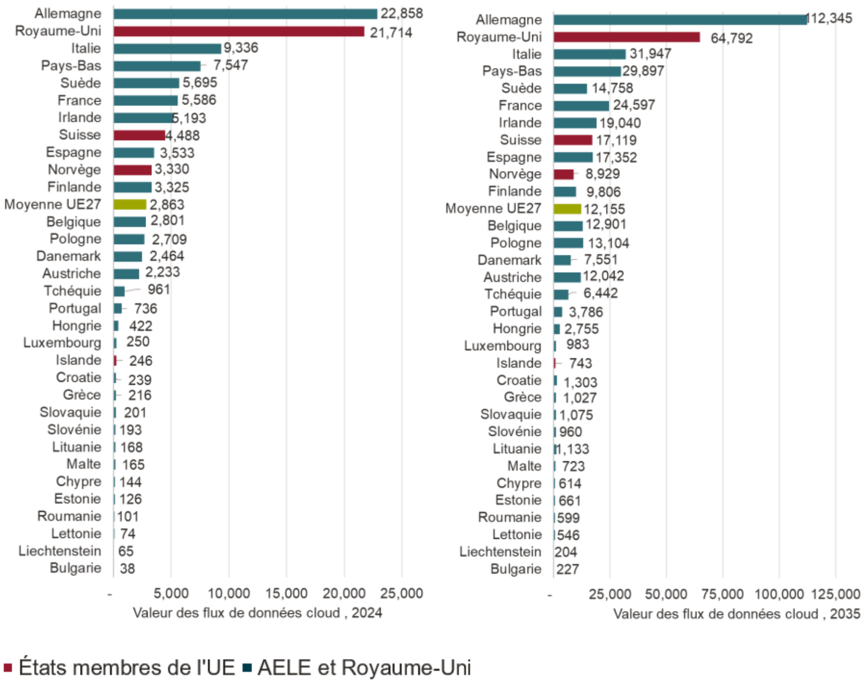
[11] En effet, le volume de flux de données cloud généré dans quatre de ces cinq pays (Islande, Luxembourg, Malte et Chypre) par rapport à la taille relative de leur économie (mesurée par leur VAB) est conforme à la moyenne européenne. Le ratio des flux de données cloud générés par rapport à la VAB au Liechtenstein est inférieur à la moyenne européenne, en raison de la faible adoption des services cloud dans ce pays ; cependant, même si ce ratio était identique à la moyenne européenne, le Liechtenstein se classerait toujours parmi les cinq derniers pays en termes de flux de données cloud générés en son sein.

[12] En d'autres termes, si un pays génère 1EX/mois de flux de données cloud et qu'un autre pays génère 5EX/mois, il n'est pas nécessairement vrai que le second pays peut extraire cinq fois plus de valeur des flux de données cloud que le premier.

2, **l'Irlande, la Finlande, les Pays-Bas et la Suède se classent tous nettement mieux en matière de valeur des flux de données cloud qu'ils génèrent, par rapport à leur volume**. La criticalité des flux de données cloud est particulièrement élevée dans ces pays, ce qui explique pourquoi la valeur des flux de données cloud pour l'Irlande, la Finlande, les Pays-Bas et la Suède est élevée par rapport au volume de flux de données que ces pays génèrent.

Figure 6 Valeur économique des flux de données cloud en 2024 par pays, en millions d'euros



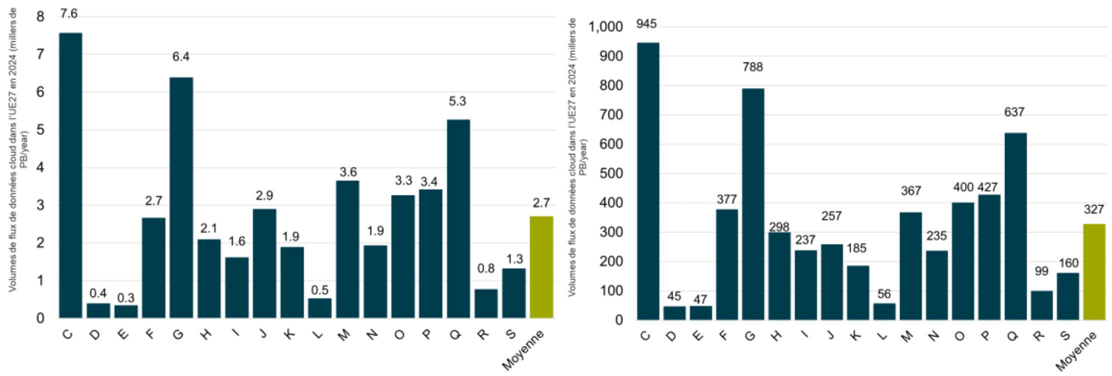
Comme pour le volume de flux de données, la répartition de la valeur des flux de données cloud entre les pays européens devrait également rester globalement stable au fil du temps. Comme le montre la figure 2 ci-dessus, les cinq derniers pays en terme de valeur économique générée par les flux de données en 2035 devraient être les mêmes qu'en 2024. Concernant, les pays générant le plus de value économique dûe aux flux de données est largement stable entre 2024 et à l'horizion 2035. Cependant, la France, l'Irlande, l'Espagne et la Suisse devrait dépasser la valeur économique générée en Suède dûe aux flux de données en raison d'une croissance plus rapide de l'adoption des services cloud dans ces pays comparée à la Suède.

Cette étude estime également comment le volume des flux de données cloud et la valeur économique de ces flux de données cloud pour les entreprises qui utilisent des services cloud varient en fonction du secteur économique et de la taille d'entreprise. Par souci de concision, nous présentons ci-dessous les chiffres pour l'UE, mais les réultats sont très proche pour l'AELE et le Royaume-Uni.

Volume et valeur des flux de données cloud dans l'UE par secteur économique et taille d'entreprise

Comme le montre la figure 3 ci-dessous, les trois secteurs qui devraient générer les plus grandes quantités de flux de données cloud en 2024 sont : l'industrie manufacturière (code NACE C, 7 600 PB/an), le commerce de gros et de détail (code NACE G, 6 400 PB/an), la santé humaine et l'action sociale (code NACE Q, 5 300 PB/an). Cela s'explique par le fait qu'il s'agit des secteurs qui comptent le plus grand nombre de travailleurs (en moyenne) en Europe (UE + AELE + Royaume-Uni) et que l'utilisation du cloud dans ces secteurs est relativement élevée[13]. Inversement, les secteurs les moins importants en termes de génération de flux de données cloud sont l'électricité (D), la distribution d'eau (E), l'immobilier (L) et les arts (R).

Figure 7 Volume des flux de données cloud dans l'UE par secteur économique de la NACE (en milliers de PB/an), 2024 et 2035



Note : C=Industrie manufacturière ; D=Fourniture d'électricité, de gaz, de vapeur et d'air conditionné ; E=Fourniture d'eau ; assainissement, gestion des déchets et dépollution ; F=Construction ; G=Commerce de gros et de détail ; réparation d'automobiles et de motocycles ; H=Transport et entreposage ; I=Hébergement et restauration ; J=Information et communication ; K=Activités financières et d'assurance ; L=Activités immobilières ; M=Activités professionnelles, scientifiques et techniques ; N=Activités de services administratifs et de soutien ; O=Administration publique et défense ; Sécurité sociale obligatoire ; P=Éducation ; Q=Santé humaine et action sociale ; R=Arts, spectacles et activités récréatives ; S=Autres activités de services.

Conformément aux résultats nationaux présentés précédemment, un volume plus élevé de flux de données cloud ne se traduit pas nécessairement par une valeur économique générée plus élevée. Cette différence de répartition entre le volume et la valeur est à nouveau due à la criticalité des flux de données cloud pour les utilisations sectorielles des services cloud, telle que mesurée par l'indice de criticalité des flux de données (« *Data Flows Criticality Index* », DFCI). Nos estimations indiquent que la criticalité des flux de données cloud est plus élevée dans les secteurs de l'information et de la communication, de l'immobilier et des services professionnels, par rapport aux secteurs de la santé et de l'aide sociale et aux autres secteurs[14].

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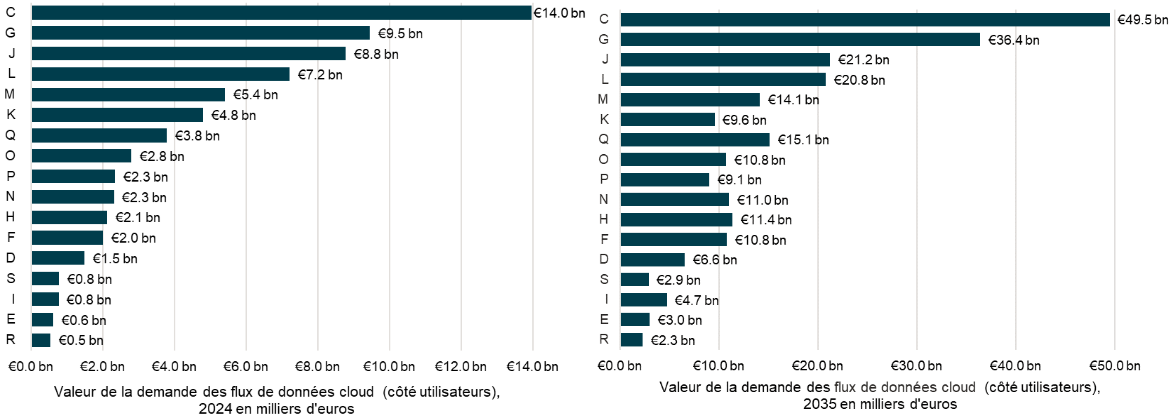
[13] L'analyse des flux de données cloud par secteur n'inclut pas les secteurs A (agriculture, sylviculture et pêche) et B (industries extractives) de la NACE. Les données sur l'utilisation du cloud et les autres indicateurs nécessaires à l'estimation des flux de données cloud provenant de ces secteurs ne sont pas disponibles.

[14] Dans le cas de l'immobilier, la valeur relativement élevée des flux de données cloud par rapport à leur volume est également susceptible de s'expliquer en partie par la forte intensité capitalistique de ce secteur. Une forte intensité capitalistique signifie qu'il y a relativement peu de travailleurs dans ce secteur par rapport à d'autres, ce qui signifie que ce secteur génère moins de flux de données cloud. Toutefois, les données se rapportent à de grands volumes d'actifs et sont donc liées à une VAB élevée.

Figure 8 Valeur économique du côté de la demande (utilisateurs) générée par les flux de données cloud au sein de l'UE en 2024 et 2035, par secteur



Note : les codes sectoriels sont identiques à ceux de la figure 3.

La valeur économique du côté de la demande des flux de données cloud pour les entreprises utilisatrices du « cloud » au sein de l'UE en 2024 (69,2 milliards d'euros) se répartit à peu près également entre les petites et moyennes entreprises (PME) (34 milliards d'euros) et les grandes entreprises (35,1 milliards d'euros). Toutefois, si l'on ajoute la valeur économique des flux de données cloud du côté de l'offre (i.e. pour les fournisseurs de services cloud), presque exclusivement générée par les grandes entreprises, on constate que les grandes entreprises représentent environ 56 % de la valeur économique générée par les flux de données cloud contre 44 % pour les PME en Europe.

Nos prévisions indiquent que la répartition du volume et de la valeur économique générée par les flux de données cloud par secteur et taille d'entreprise devrait rester similaire jusqu'en 2035.

Tendances actuelles et futures relatives au volume et à la valeur générée par les flux de données cloud en Europe et au-delà

Cette étude estime qu'en 2024, un peu plus de **57% (26 300 PB/an de flux de données cloud)** des 46 000 PB/an de flux de données cloud généré par les entreprises utilisant des services cloud au sein de l'UE **resteront dans leur pays d'origine. Environ un cinquième (10 000 PB/an) circulera vers d'autres pays européens (AELE, Royaume-Uni) et environ un sixième (7 100 PB/an) circulera vers des régions non-européennes.**

La proportion des flux de données cloud qui reste en Europe devrait augmenter avec le temps, passant de 84% en 2024 à 90% en 2035. Cela s'explique par le fait qu'une proportion croissante de flux de données cloud devrait être dirigée vers des centres de données périphériques (centre edge), et que l'une des hypothèses du modèle économique développé est que tous les flux de données cloud qui circulent vers des centres de données périphériques restent tous en Europe (en circulant vers le centre de données edge européen le plus proche).

La valeur en jeu des flux de données cloud extracommunautaires est importante. En effet, en 2024, environ 15,6 milliards d'euros de valeur économique générée par les flux de données cloud au sein de l'UE ont pour destination un pays non-européen comme s'en suit :

- **3,2 milliards d'euros** vers les pays de l'AELE ;
- **0,6 milliard d'euros** vers le Royaume-Uni ; et
- **11,8 milliards d'euros** vers l'Amérique (2,6 milliards d'euros), le Moyen-Orient (4,3 milliards d'euros), l'Afrique (1,9 milliard d'euros) et l'Asie (3 milliards d'euros).

1. Introduction

a. Objectives

This report is commissioned by the European Commission, Directorate-General for Communications Networks, Content and Technology (DG CNEC) to Frontier Economics Ltd. (hereinafter the "Frontier team", "Frontier" or "we").

It is the main deliverable of the "Data Flow and Economic Value EU Framework: Modelling Update and Data Collection" project (CNECT/2021/OP/0046), together with:

- The online data visualisation tool, which presents a wider set of data points and levels of granularity compared to this report on European cloud-based data flows (ECBDFs), which instead focuses on key insights and findings; and
- The methodology note (or methodological note), which describes and explains in detail the conceptual frameworks and the methodologies developed to obtain the estimates presented in this report and in the online data visualisation tool.

This project, in the context of former European Commission's studies on mapping data flows and economic values of data flows, aims to achieve *"three main complementary objectives:*[15]

- *In-depth assessments of underlying quantitative and qualitative methodologies, databases, models, analytical frameworks and tools developed so far:*
    - *to map intra- and extra-EU data flows;*
    - *to estimate economic values of data flows and;*
    - *to forecast the data flow growth rate and impacts to the economy in terms of GDP, competitiveness, sustainability, investments and trade.*
- *Provision of an enhanced analytical framework for mapping data flows, an enriched methodology to estimate economic values and improved models to forecast growth rate and impacts of data flows to the economy based on the gaps identified in the existing methodologies.*
- *Data collection at scale to update the EU interactive data flow tool to be hosted on the European Commission's website with the latest available data on at least the following:*
    - *location and volume of main intra- and extra-EU data flows;*
    - *economic values of data flows; and*
    - *forecasts of data flow growth rate and impacts to the economy"* [until 2036].

b. Definitions

The main focus of this report is on enterprise cloud-based data flows (ECBDFs): i.e. flows of data triggered by enterprises that use cloud services.

15 These are highlighted on page 5 of the tender specification document and described in detail on pages 8 and 9 of the same document. For the sake of brevity, we do not present the tender requirements in detail in this report.

The origin of ECBDFs is the country where the enterprise that triggers the flow is located. Their destination is the country where the cloud/edge data centre of the cloud provider used by the enterprise is located.

Due to the novelty and complexity of this research area, it is essential to clearly define each component of the acronym ECBDF. More specifically:

- **Enterprise:** we focus only on data flows triggered by enterprises (e.g. an energy company that stores files on the cloud) and not on flows triggered by consumers (e.g. an individual who stores pictures on Dropbox). Enterprises can be private and public sector organisations.[16]
- **Cloud-based:** we focus exclusively on data flows triggered by the use of cloud services by enterprises (e.g. a manufacturing company that uses a cloud-based customer relationship management (CRM) platform to manage relationships with its distributors) and not on flows triggered by enterprises' use of the internet in general (e.g. the same company using a market research website to gain information about potential clients).
    - **Cloud data centres**: data centres that are operated by cloud providers, including both "main" cloud data centres and "edge" data centres. We use the expressions "cloud data centres" and "cloud facilities" interchangeably in this report.
    - **Main cloud data centres and edge data centres:** our analysis distinguishes between enterprise cloud data that flows to main cloud data centres and data that flows to edge data centres.[17] We use the expressions "edge data centres" and "edge facilities" interchangeably in this report.
- **Data flows:** we focus only on data that flows from the enterprise to the data centres of cloud providers (hereinafter enterprise-to-cloud infrastructure or E2C flows) and not on flows that occur within or between cloud providers' infrastructures (cloud infrastructure-to-cloud infrastructure or C2C flows).
- **Europe:** this dimension is not included in the ECBDF acronym, but it is important to highlight the geographical focus of this research. We include in our analysis only ECBDFs generated by enterprises operating in EU countries, as well as in the European Free Trade Association (EFTA) (Iceland, Liechtenstein, Norway and Switzerland) countries and the UK. We refer to these 32 countries collectively as "European" and in all tables and charts we clearly distinguish between these different groups of countries.
- **Rest of the world:** this report also analyses ECBDFs that flow from European countries to non-European regions and countries (e.g. from France to the USA and Canada or from the UK to China). However, it does not analyse ECBDFs that flow in the opposite direction (e.g. from the USA to France), because data on ECBDFs generated by non-European countries is not available and Eurostat only covers EU, EFTA and the UK.

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[16] The starting point of our analysis is the data collection on enterprise cloud uptake published by Eurostat. As the Eurostat data collection on enterprise cloud uptake does not include many segments of the public sector, a representative sector has been used as a proxy for public sector cloud uptake. More details on this are provided in the methodological note.

[17] Using the latest information published on the 2023 Report on the State of the Digital Decade: https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade. Our analysis of edge centres is consistent with the taxonomy and the definitions published by the EU edge observatory: https://digital-strategy.ec.europa.eu/en/policies/edge-observatory#tab_2

- **Within-country ECBDFs**: the volume of ECBDFs that flow from enterprises in each European country to cloud facilities within the same country.
- **Inter-country ECBDFs**: the volume of ECBDFs that flow from enterprises in each European country to other countries (broken down by country of destination).
- **Net inflow of ECBDFs**: we calculate the net inflow of ECBDFs to a given European country, equal to the difference between the ECBDFs that leave a specific country and the ECBDFs that flow into the same country.
- **Internet traffic:** the flow of data within the entire internet, or in certain network links of its constituent networks. Internet traffic is composed of data flows that stem from any activities that occur over the internet. Data flows can be triggered either by enterprises (**enterprise data flows**) or individuals' consumption of any services used over the internet (**individual data flows**).

These definitions were used consistently throughout the different phases of our analysis and apply to all the findings and results presented in the following sections and chapters.

c. Policy relevance

In the context of DG CNECT's high-level objective of developing and implementing policies to make Europe fit for the digital age, this study and the online data visualisation tool are expected to:

- Help assess and improve one of the key actions of the EU Data Strategy: *"the creation of a framework to measure data flows and estimate their economic value within Europe as well as between Europe and the rest of the world"*;
- Inform discussions on how to achieve the EU's digital decade targets, in particular the cloud and edge computing targets, which aim for 75% of EU companies to be using cloud/AI/Big Data by 2030, and the deployment of 10,000 climate-neutral and secure edge nodes across the EU, by providing up-to-date data on cloud uptake and forecast up to 2036. This is why our methodology (as explained in more detail below) distinguishes between ECBDFs that flow to main data centres and ECBDFs that flow to edge centres;
- Contribute to policy discussions on the European Industrial Strategy, providing economic intelligence on the location of main and edge cloud data centres as well as on the magnitude, origin and destination of cloud data flows;
- Provide up-to-date data to inform the ex-post evaluation of the regulation (2018/1807) on the free flow of non-personal data;
- Provide up-to-date evidence on cloud-based data flows to enable strategic decision-making, for instance, on future investment in cloud and edge computing capabilities. For example, it could inform the upcoming DIGITAL and CEF2 work programmes as part of the review and future Multiannual Financial Framework (MFF) negotiations; and
- Support decision-making, industrial choices and investment decisions as well as future international trade negotiations and the governance of international data flows (this objective explains the focus of this study both on intra-European ECBDFs and on ECBDFs that flow to other regions).

d. Broader considerations

As mentioned above, this is a particularly novel and complex research area. To our knowledge, there are only two publicly available studies worldwide that focus on ECBDFs, both commissioned and published by DG CNECT:

- The first one, produced by Valdani Vicari & Associates (hereafter the "VVA report" or "VVA study"), was published in 2021. It focused only on the volume and location of ECBDFs.[18]
- A second one was published in 2023 by Ipsos and Tech4i2 (hereafter "Ipsos/Tech4i2 report" or "Tech4i2 report"). It focused on the economic value of ECBDFs.[19]
- The results of both studies are currently presented on the online data visualisation tool, which is the only publicly available source of data on cloud-based data flows at the time of writing this report.[20]

The main challenges that our study attempts to overcome are:

- The absence of any research (apart from the two studies mentioned above) that focuses on the measurement and economic value of cloud-based data flows;
- The fact that the four main features that define ECBDFs and that are listed in the bullets above (enterprise, cloud-based, E2C flows from Europe) are sometimes blurred, making it challenging to draw a line between an ECBDF and a data flow that does not fully fit in the definition provided above.
    - This complexity is particularly pronounced when conceptualising and estimating the economic value of ECBDFs, as the distinction between the economic value of ECBDFs and the economic value of the cloud services that trigger the flows (and/or of the data-intensive activities performed using these services) is not always clear and distinct; and
- The need to use reliable publicly available (and free of charge) data to estimate the volume, the location and the economic value of ECBDFs in a way that could be easily updated and replicated by DG CNECT and by other studies and researchers in the future. This aspect is particularly challenging in light of the absence of existing research or data on the topic, as described in the bullets above.

The articulation of these challenges also highlights the main contributions of this report:

- It sheds light on a topic that has not previously been analysed in detail and that will become increasingly important in the upcoming years in light of the expected growth of cloud services in Europe and around the world more generally. This report provides novel economic intelligence in the cloud field to enable evidenced-based policy and investment decisions that reflect market and consumer realities.
- It is the first piece of research to explore in detail ECBDFs that flow to non-European countries, using publicly available information on submarine cables and intercontinental connecting infrastructures as well as public information on the location of the extra-European main cloud data centres operated by major cloud providers. It is also the first study that attempts to account for ECBDFs triggered by the use of on-premises cloud services.
- The methodologies and the conceptual frameworks presented in this report provide a new and innovative way to isolate the economic value of ECBDFs from the value of cloud services more generally. To our knowledge, this report includes the first conceptual framework to focus on ECBDFs and based on economic theory.

[18] https://digital-strategy.ec.europa.eu/en/library/study-mapping-data-flows

[19] https://digital-strategy.ec.europa.eu/en/library/economic-value-data-flows

[20] https://digital-strategy.ec.europa.eu/en/policies/european-data-flow-monitoring

- Together with the VVA report and the Ipsos/Tech4i2 report, it is the only study that analyses current and future ECBDFs that flow to main cloud centres and edge facilities respectively.
- The frameworks and the results presented in this report are exploratory and based on a variety of evidence-based assumptions, but they can be used as a starting point for future research on ECBDFs. This is because all the methodologies and calculations that underpin the results presented in this report are based on free, publicly available data as well as on clear and transparent assumptions that could be updated and modified in the future by the Commission's services.

e. Structure of the report

The deliverables of this project are structured as follows:

- The main report focuses on the key results and insights that emerged from this study.
- The online data visualisation tool presents a wider set of data points and levels of granularity.
- The methodology note explains in detail the frameworks developed to conceptualise the volume and value of ECBDFs and the methodologies built to implement these frameworks in practice and obtain the estimates presented in this report and in the online data visualisation tool.

As a result, the rest of this report is articulated as follows:

- Chapter 2 presents the main results related to the volume of ECBDFs.
- Chapter 3 presents the main results related to the economic value of ECBDFs.
- Chapter 4 summarises the report's main findings and insights, looking at volume/location and value jointly.

In addition, as mentioned above, this report is complemented by a methodological note, which is divided into three core sections:

- The first section outlines the methodology used to obtain the results related to the volume of ECBDFs presented in Chapter 2.
- The second section describes the conceptual framework and the methodology used to produce the estimates related to the economic value of ECBDFs presented in Chapter 3.
- The third section summarises our assessment of existing literature and studies on ECBDFs, cloud services and data flows more generally.

The three core sections of the methodological note are also followed by four annexes, which provide further detail on the methodology and on the sources and research underlying our calculations.

2. Methodology

a. Overall analytical approach

As mentioned above, this is an exploratory study that investigates an emerging topic for research and that develops and deploys a novel methodology designed to achieve one of the actions of the EU Data Strategy. As such, it can be classified primarily as a methodological study.

The overall analytical approach is based on two overarching principles:

- First, the need to focus **exclusively on ECBDFs**.
  - When estimating the volume of ECBDFs, this means implementing series of calculations and assumptions to isolate ECBDFs from wider measures of internet traffic.
  - When estimating the location of ECBDFs, this means conducting research about the locations of cloud data centres and the likely direction of ECBDFs from each European country.
  - When estimating the economic value of ECBDFs, this means finding a way to isolate the value attributable to ECBDFs from the wider economic value generated by cloud services.
- Second, recognition that the **economic value of ECBDFs is not linearly related to the volume of ECBDFs**.
  - In other words, if one country generates 1EX/month of ECBDFs and another country generates 5EX/month, it is not necessarily the case that the second country can extract five times more value from ECBDFs compared to the first one. This is because the value that an organisation can extract from ECBDFs is driven by the value that these flows add to the economic activities that this organisation performs on the cloud, and not by the volume of flows per se.

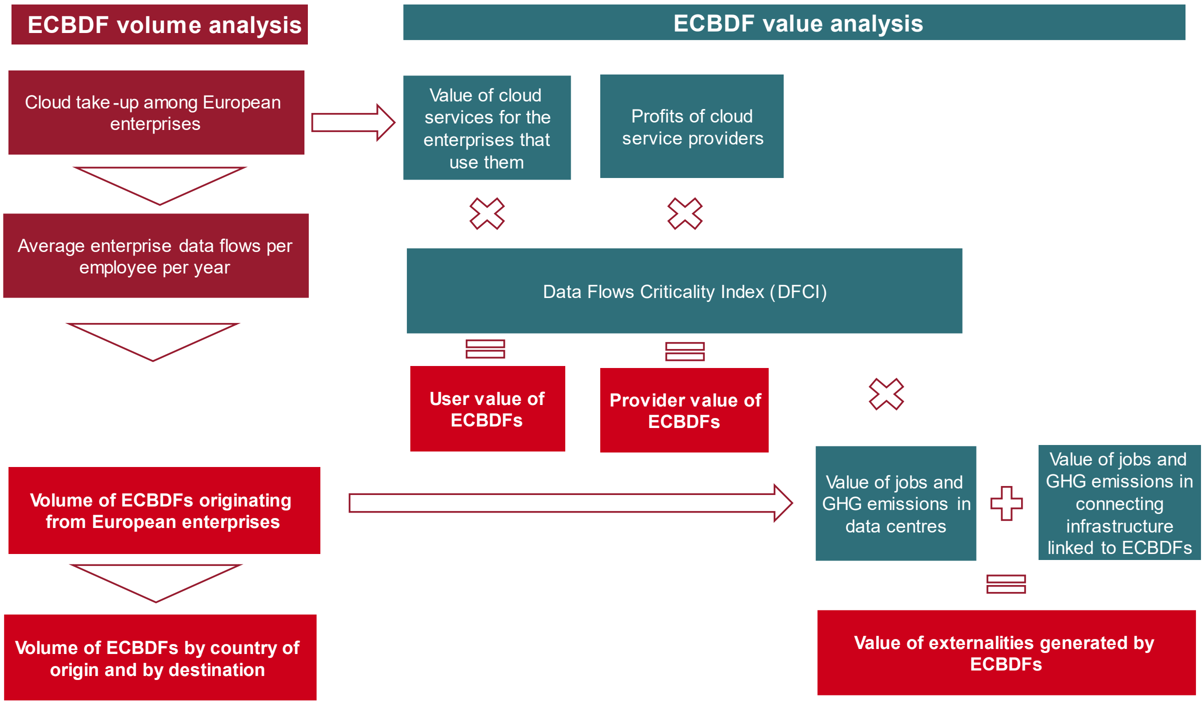
In light of these two overarching principles, we developed two distinct but complementary conceptual frameworks and methodologies to estimate:

- The **volume and location of ECBDFs** (as explained in Section b.ii below and in Chapter 3, with the first section of the methodological note providing more details on the methodology, data and assumptions used).
- The **economic value of ECBDFs** (as explained in Section b.iii below and in Chapter 4, with the second section of the methodological note providing more details on the methodology, data and assumptions used).

The fact that these two elements of our research are analysed and conceptualised separately does not mean that the results on volume/location and value cannot be compared and read jointly. Indeed, Chapter 4 presents some insights and conclusions on the main results that emerged from both in our analysis.

The framework is illustrated at a high level in Figure 2.1 below and described in the following sections of this chapter. Further detail is provided in the methodological note accompanying this report, which includes a detailed explanation of our calculations, the assumptions and data sources used for each step, the various alternative assumptions and data sources we considered in the course of the project, as well as the reasons why we chose some specific assumptions and sources and not others. The methodological note will be particularly helpful for researchers who wish to try to replicate, expand and improve the exploratory analysis presented in this report.

Figure 2.1 Illustration of methodological approach



b. Methodology used to estimate the volume of ECBDFs

i. Objectives

Our analytical framework is the basis for estimating the volume of ECBDFs that are triggered by the use of cloud services by enterprises in each European country and the final destination (location) of the ECBDFs.

The study estimates the **volume of ECBDFs** that originate from enterprises that operate in Europe.[21] We estimate ECBDFs **by country of origin** (the geographical country where the enterprise that triggers the ECBDF through the use of cloud services is located). We sum these country-level volumes up to aggregated Europe totals for the EU, EFTA and the UK. We also break down the volume of ECBDFs generated in each country by NACE sector of the enterprises that trigger the ECBDFs and by enterprise size band (i.e. small, medium and large enterprises).[22]

Having estimated the volume of ECBDFs by country of origin, we also assess **the destination of these flows** by country and region including beyond Europe. Specifically, the key quantities we estimate are the following:

- Within-country ECBDFs: the volume of ECBDFs that flow from enterprises in each European country to cloud data centres (both main data centres and edge facilities) within the same country;

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[21] Note that this includes both European-owned enterprises and enterprises owned by individuals who are not citizens of European countries or by entities that are not headquartered in a European country.

[22] We do not provide estimates broken down by cloud service type because, while cloud-use statistics by service type are published by Eurostat, we did not find in the literature a systematic way to quantify differences in cloud-use intensity between different service types.

- Inter-country ECBDFs: the volume of ECBDFs that flow from enterprises in each European country to other countries, including both European and non-European countries (broken down by country of destination);
- The net inflow of ECBDFs in a given European country (i.e. the difference between the ECBDFs that leave a specific country and the ECBDFs that flow into the same country);
- The volume of ECBDFs processed within each European country: the sum of within-country ECBDFs plus ECBDFs that flow to this country from other countries;
- Intra-EU ECBDFs: the volume of ECBDFs that originate from EU countries that remain within the country of origin, plus the volume that flow to other EU countries;
- Extra-EU ECBDFs: the volume of ECBDFs that flow from EU countries to non-EU countries; and
- Main and edge ECBDFs: the volume of ECBDFs that flow from enterprises in each European country to main cloud data centres and to edge facilities.

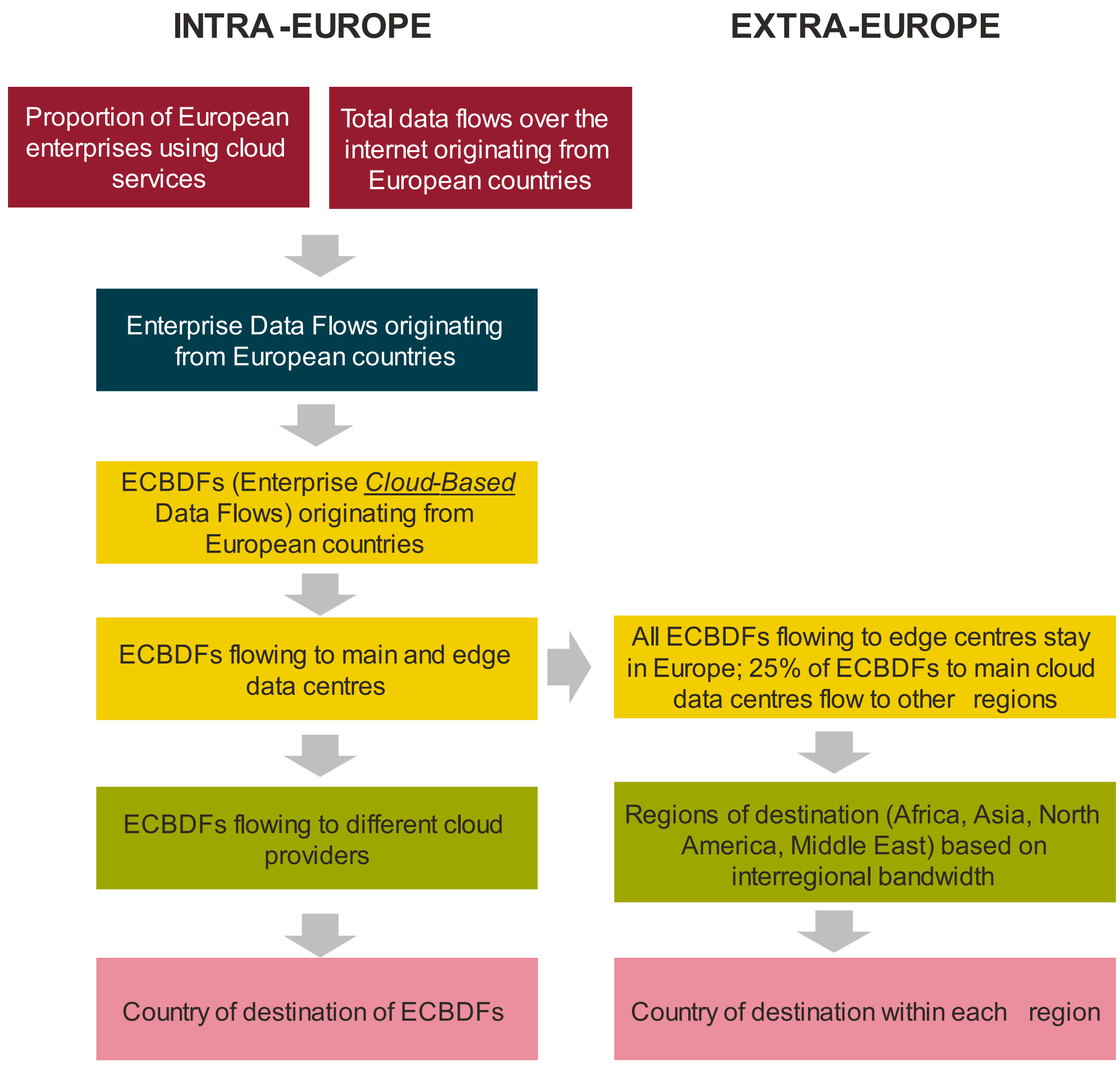
We also aggregate our estimates to produce various totals and produce further breakdowns that can be found in the main report or in the online data flow monitoring tool. These estimates are all part of the same consistent and coherent framework.[23]

All our volume estimates cover a 20-year period from 2016 to 2036.

Figure 2.2 below summarises our approach to producing these estimates. The following sections describe the approach in more detail, focusing first on estimating the volume of ECBDFs by country of origin (Section 2.b.ii), and then on estimating the destination of the ECBDFs (Section 2.b.iii).

23 Against this backdrop, there are some data sources and assumptions that are used only to estimate extra-Europe ECBDFs and not intra-Europe ones – for example, public information on submarine cables and inter-continental internet bandwidth.

Figure 2.2 Graphical summary of methodology to estimate volume and location of ECBDFs

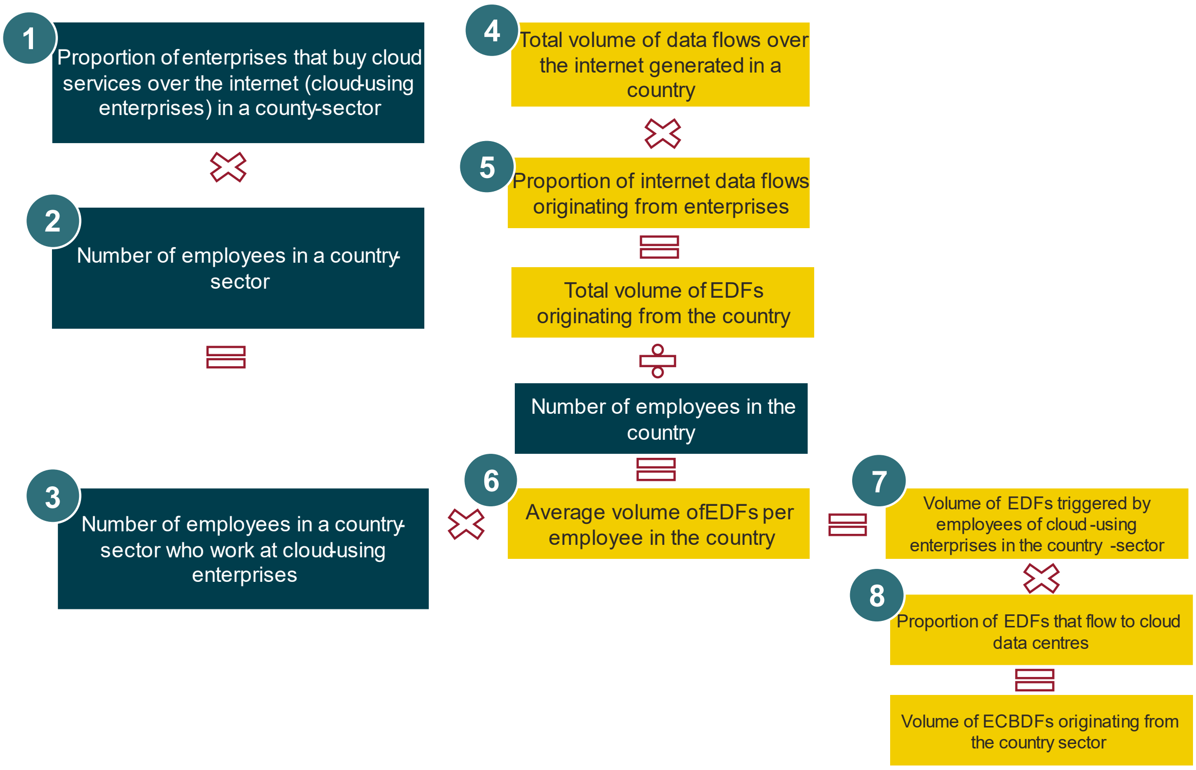


ii. Estimating ECBDF volume by origin

This section describes our approach to estimating the volume and location of ECBDFs triggered by the use of cloud services by enterprises in Europe.

Our approach is summarised in Figure 2.3 and is described in more detail below, using the calculation of ECBDFs that originate from the Spanish manufacturing sector as an example.

Figure 2.3 Graphical summary of methodology to estimate volume of ECBDFs by *country and sector of origin*



1. We start from Eurostat data on the proportion of enterprises that buy cloud services over the internet (cloud-using enterprises) in a given country-sector. For example, this is 30% of enterprises in the Spanish manufacturing sector (step 1).

2. We then collect data from Eurostat on the number of workers in each country-sector. For example, there are 1 million employees in the Spanish manufacturing sector.

3. We then estimate the number of workers in each country-sector that are employed by cloud-using enterprises. To do this, we multiply the proportion of enterprises that buy cloud services over the internet from step 1 by the total number of employees in each country-sector (step 2). For example, there are 1 million employees in the Spanish manufacturing sector. We estimate that out of these 1 million workers, 300,000 are employed in enterprises that use cloud services (1 million total workers employed in this sector, multiplied by 30%).[24]

We do this because ECBDFs are triggered by employees' use of cloud services. Therefore, a sector that employs more workers is expected, all else equal (e.g. number of enterprises in a given sector), to generate a greater volume of ECBDFs.

The number estimated at step 2 is the number of employees who work at cloud-using enterprises. Given that cloud services are bought over the internet, this study estimates

[24] Note that we do not assume that all employees who work in cloud-using enterprises use cloud services, nor that they all use cloud services to the same extent. This becomes clearer when we explain steps 5 and 6 in the calculation.

ECBDFs as a proportion of total internet traffic. Internet traffic is composed of data flows (DFs) that stem from any activities that occur over the internet. Data flows can be triggered either by enterprises' or individuals' consumption of any services used over the internet.

However, this study solely focuses on quantifying the volume of data flows (i) triggered by enterprises (ii) that use cloud services (iii) over the internet (i.e. ECBDFs). Therefore, the next steps in our calculation must:

- Start by estimating the total volume of data flows over the internet (DFs) ;
- Then estimate the share of DFs triggered by enterprise activities over the internet (EDF) as opposed to the ones triggered by individuals (IDFs); and
- Finally, identify the share of enterprise data flows triggered exclusively by the consumption of cloud services (ECBDFs).

This is implemented as follows:

4. We start from data sources on total internet traffic which is available at country level from the International Telecommunications Union (ITU).[25] For example, we know that the total internet traffic generated in Spain in 2023 was 90,000 PB. However, as explained above, this includes not only data flows triggered by enterprises ("enterprise data flows") but also data flows triggered by individuals.
5. Our elaboration of data from Cisco indicates that 22.5% of total internet traffic stems from enterprise activities. We thus assume that the proportion of internet traffic that EDFs represent is 22.5% of total internet traffic. This allows us to estimate the PB/year of EDFs in Europe by country. For example, in Spain in 2023 there were around 20,000 PB of EDFs (the rest being IDFs but out of scope of this analysis).
6. We then divide this volume of EDFs by the total number of employees in a given country (obtained from Eurostat), to obtain an average volume of EDFs per employee. For example, there are about 20 million employees in Spain. Therefore the average volume of EDFs per employee in Spain is 0.001 PB.
7. We multiply the average EDF per employee by the number of employees at cloud-using enterprises in a given country-sector to obtain the total volume of EDFs triggered by cloud-using enterprises in that country-sector.[26] In the case of the Spanish manufacturing sector, this is around 710,000 employees * 0.001 PB = 710 PB of EDFs triggered by cloud-using enterprises in 2023 in the Spanish manufacturing sector.

Note that the figure estimated at step 7 is not yet the volume of ECBDFs. While the 750 PB EDFs estimated in the Spanish manufacturing example are all triggered by employees working in cloud-using enterprises, only a proportion of these EDFs are ECDBFs (enterprise data flows triggered by employees' consumption of cloud services). This is because the intensity of cloud usage may differ between employees working at enterprises that use cloud services. Employees may still trigger non-cloud data flows through other activities that take place over the internet in their daily professional activities but that are not cloud-based activities. An example of this could be a multinational manufacturing enterprise which uses cloud services for most of its IT and data activities, but still hosts its human resources (HR) records on a

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[25] To obtain total internet traffic, we add up the ITU's estimates of mobile internet traffic and fixed internet traffic.

[26] Note that this involves an assumption that the average volume of EDF per employee is the same among cloud-using enterprises and non-cloud-using enterprises. This is a conservative assumption as, in practice, firms that use cloud services are likely to have more digital-intensive and data-intensive activities. For example, our analysis of Eurostat data, reported in Section 3 of the methodological note, shows that there is a positive correlation between the use of some types of cloud services and the use of Big Data analysis and artificial intelligence (as defined by Eurostat).

legacy database that is hosted through an on-premises non-cloud server. In this example, most employees of this manufacturing multinational use cloud-based software (e.g. data scientists and data engineers using analytics to optimise the production process), which triggers ECBDFs. However, when the head of HR at the firm uploads the details of a new employee onto the HR database, this triggers a non-cloud EDF.

Therefore, to obtain the volume of ECBDFs, we undertake the following final step in the calculation:

8. We multiply the volume of EDFs estimated at step 7 by an estimate of the proportion of EDFs that will flow to cloud and edge data centres due to the consumption of cloud services by enterprises over the internet in a given country-sector. **The result of this calculation is the volume of ECBDFs that originate from that country-sector**. The estimate of the proportion of EDFs used is 37%. This estimate comes from a combination of data points from the Tech4i2 study, a Palo Alto and a Thales Group study (see further details in section 3 of the methodological note for the exact percentage calculation). Applying this figure to our Spanish manufacturing example, we estimate that the total volume of ECBDFs that originate from this sector is 710 PBs * 37% = 263 PB.

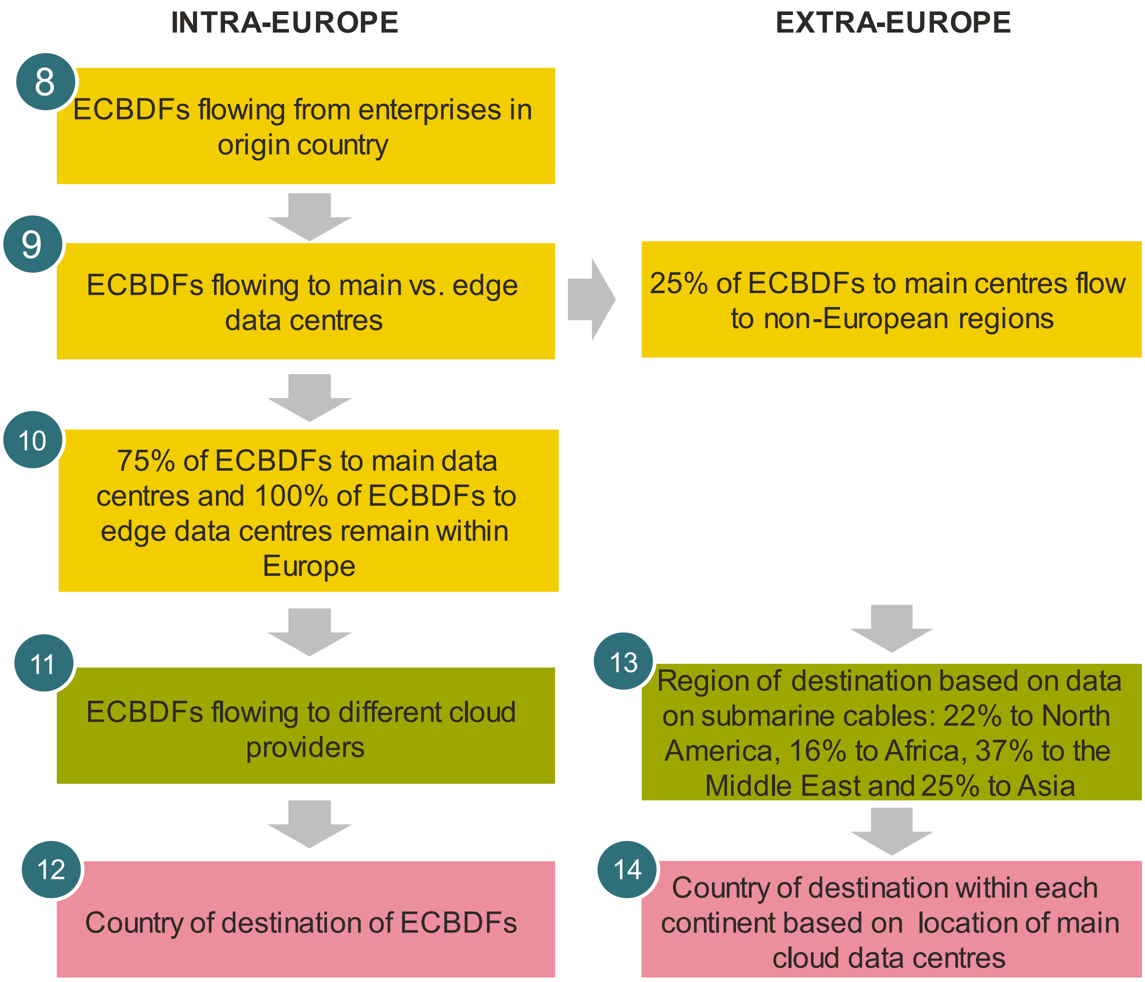
To finally obtain the volume of ECBDFs in each country (e.g. Spain) we add up the volume of ECBDFs estimated for each sector in that country (step 8 above). In the case of Spain, the sector-level estimates add up to 2,500 PB of ECBDFs generated in 2023.

iii. Estimating ECBDF volume by origin and destination of flow

Step 7 described above allows us to estimate the volume of ECBDFs that originate from each country and each country-sector (e.g. Spanish manufacturing) in Europe. The next steps in our methodology aim to estimate the volume of ECBDFs that flow to each country of destination from a given country of origin, within and outside Europe. We describe the steps involved in our calculation below, starting from step 8.

As above, we illustrate these steps through an example: estimating the country of destination of ECBDFs triggered by the use of cloud services made by Spanish enterprises. Due to the greater complexity of these calculations compared to those illustrated above with the example of the Spanish manufacturing sector, here we first describe the approach in general terms, and then apply the approach to the example in a separate box.

Figure 2.4 Graphical summary of methodology to estimate volume of ECBDFs by *country of destination*



The general steps we undertake are as follows:

9. Estimate the proportion of ECBDFs that flow to main versus edge data centres. To do this, we combine assumptions made in previous reports on European ECBDFs with data on the cloud and edge targets set out in the European Commission's 2023 report on the State of the Digital Decade. In 2023, we assume that the proportion of ECBDFs that flow to main data centres is 68%, with the remaining 32% flowing to edge facilities.
10. Estimate the proportion of ECBDFs that remain within Europe versus that which flow to countries outisde Europe.
    a. We assume that 100% of the ECBDFs that flow to edge data centres remain within Europe, as by definition edge facilities are located in close proximity to the cloud-using enterprises that trigger the ECBDFs.
    b. Based on data from TeleGeography, we assume that 25% of ECBDFs that flow to main data centres (25% of 68%) flow to main data centres outside Europe.
11. Estimate the proportion of ECBDFs that flow to each cloud services provider. We assume that the proportion is equal to each provider's revenue market share in the EU market, obtained from the Dutch competition authority's recent study of the cloud

market.[27] We apply the same proportion to ECBDFs that flow to main data centres and ECBDFs that flow to edge facilities.[28]

The next steps are slightly different for the intra-Europe versus extra-Europe ECBDFs.

For Intra-Europe ECBDFs:

12. We estimate the volume of ECBDFs assigned to each cloud service provider that flow to each European country. We identify the location of main and edge data centres based on the information provided publically by cloud providers, which we collated into a consolidated database. Based on the information in this database:
    a. If a given provider (e.g. AWS) has a data centre in the country of origin in which the ECBDF was initially triggered, then all ECBDFs that flow to that provider are assumed to remain within the country of origin.
    b. If a provider (e.g. IBM) does not have a data centre in the country of origin in which the ECBDF was initially triggered, then the ECBDFs are assumed to flow to the closest country (or countries) where that provider has a data centre.
    c. If the cloud provider has a data centre in two countries that are equally close to the country of origin, then the ECBDFs are split equally between those two countries.

    This process is repeated in the same way for both ECBDFs that flow to main data centres and ECBDFs that flow to edge data centres.

For extra-Europe ECBDFs:

13. We estimate the volume of extra-Europe ECBDFs triggered in Europe that flow to main data centres in each non-European region that Europe is directly connected to through interregional bandwidth (Africa, North America, Asia and the Middle East). We do this by assuming that the proportion of the extra-Europe ECBDF volume that flows to each region is the same as that region's share of total international bandwidth which connects Europe to that region. These continental shares are sourced from TeleGeography.
14. Within each region (e.g. North America), we then estimate the proportion of ECBDFs that flow to each country based on the location of the cloud providers' main data centres within that region.

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27 This implies an assumption that cloud service providers' market shares in EFTA and the UK are equal to their market shares in the EU. We also assume that the market shares of each cloud service provider are the same between all European countries in scope of this study with the exception of the Netherlands, where we use the specific country market shares published by the Dutch competition authority. For example, AWS's market share of the French cloud services market is assumed to be the same as its share of the Belgian market, and both are assumed to be the same as AWS's share of the overall EU market. This is because there is no publicly available data on cloud providers' market shares in individual European countries with the exception of the Netherlands, where we use the specific country market shares published by the Dutch competition authority.

28 This is because there is no publicly available information that allows us to determine cloud provider shares specific to the ECBDFs that flow to edge facilities.

A practical example of estimating the destination of European ECBDFs

As described in the previous subsection of this chapter, we estimate that cloud-using enterprises that operate in Spain generated 2,500 PB of total ECBDFs in 2023. We illustrate below how we estimate the destination of these ECBDFs. To simplify the calculations for illustration purposes, we assume that there are only two cloud providers operating in Spain: CP1 and CP2. These providers have shares of the EU cloud services market of 60% and 40% respectively. CP1's data centres in Europe are an edge facility in Spain and a main data centre in Portugal. Outside Europe, CP1 operates a main data centre in the USA and one in Canada. CP2 has a main and an edge data centre in Spain and a main data centre in the USA.

- We assume that 68% of ECBDFs flow to main data centres, while 32% flow to edge data centres. For Spain, this is 1,700 PBs flowing to main data centres and the remaining 800 PB flowing to edge facilities.
- We assume that all 800 PB that flow to edge facilities remain within Europe.
- We assume that 25% of the 1,700 PB that flow to main data centres flow to main data centres outside Europe: this is 425 PB flowing to main data centres outisde Europe.
- The intra-Europe ECBDFs are assigned to the country of destination (including the same country they originated from, in this example Spain) according to the location of the cloud providers' main and edge data centres.
- Because cloud provider CP1 has a 60% market share of the EU market, and we assume that Spanish market shares are the same as EU market shares, we assume that 60% of all Spanish ECBDFs flow to this provider. This is 60% of the 1,700 PB that flow to main data centres (1,020 PB) and 60% of the 800 PB that flow to edge facilities (480 PB): 1,500 PB ECBDFs as a whole flowing to data centres operated by CP1.
- The 480 PB that flow to CP1's edge facilities are assumed to remain within Europe. These ECBDFs are estimated to remain within Spain if CP1 has edge facilities in the country; if not, they are estimated to flow to the closest country where CP1 has an edge facility. In this example, CP1 has an edge facility in Spain.
- The same allocation approach is used for the ECBDFs that flow to CP1's main data centres in Europe. This is 75% of the 1,020 PB that flow to CP1's main data centres, that is, 765 PB. In this example, CP1 has a main data centre in France, but no main data centres in Spain. Therefore, we assume that all 765 PB flow from Spain to France.
- Because CP2 has a 40% market share of the EU market, and we assume that Spanish market shares are the same as EU market shares, we assume that 40% of all Spanish ECBDFs flow to this provider. This is 40% of the 1,700 PB that flow to main data centres (680 PB) and 40% of the 800 PB that flow to edge facilities (320 PB). Because CP2 has both main and edge facilities in Spain, all these ECBDFs are assumed to remain within Spain.
- We estimated above that 425 PB of ECBDFs flow to regions outside Europe. Based on data from TeleGeography, we estimate that approximately 22% flow to North America, 16% to Africa, 37% to the Middle East and 25% to Asia. In this example, focusing on North America for simplicity, we estimate that 93.5 PB of ECBDFs flow from Spain to North America. The same calculation is carried out for Africa, the Middle East and Asia.

- Now, as in the case of intra-Europe ECBDFs, we use cloud provider market shares and the location of each provider's data centres to allocate ECBDFs to the country of destination.
- As CP1 has 60% market share, we assume that 60% * 93.5 PB = 56 PB of ECBDFs that flow to North America flow to CP1's data centres. CP1 has a main data centre in Canada and one in the USA, so we estimate that 50% * 56 PB = 28 PB flow to Canada and the remaining 28 PB flow to the USA. This process is then repeated for Africa, the Middle East and Asia.
- The process described above is repeated in the same way to estimate the destination of EBCDFs that flow to CP2's data centres. As CP2 has a 40% market share, we assume that 40% * 93.5 PB = 37.5 PB flow to CP2's main data centres in North America. CP2's only main data centre in this region is in the USA and, therefore, we assume that all 37.5 PB that flow to CP2's main data centres in North America flow to the USA.
- Having done that, ECBDFs to CP1 and to CP2 are added up to estimate the volume of ECBDFs that flow from Spain to each country within and outside Europe.

c. Methodology used to estimate the economic value of ECBDFs

i. Objectives

As mentioned above, ECBDFs **are flows of data triggered by enterprises that use cloud services**. Their origin is the country where the enterprise that triggers the flow is located. Their destination is the country where the cloud and/or edge data centre of the cloud provider is located.

One of the main objectives of this report is to **estimate the economic value of ECBDFs, as distinct from the economic value of cloud services**, which trigger ECBDFs. We present these estimates for each country under analysis and also broken down by sector, by enterprise size and by different categories of cloud services. We also provide exploratory estimates of the economic value of ECBDFs that flow to other regions.

In 2022, the Ipsos/Tech4i2 study tried to isolate the value of ECBDFs by asking enterprises that use cloud services how much (in Euros) they would be willing to pay to maintain the *"secondary benefits"*[29] of cloud services. They then calculated an average monetary value per terabyte (TB) and multiplied it by every TB of data that flows from one country to another. This was based on the assumption that volume and value are linearly correlated with each other (i.e. if 1EX of ECBDFs is worth €1m, then 10EX are worth €10m).

As mentioned above, in our study, we recognise that the **economic value of ECBDFs is not linearly related to the volume of ECBDFs**. In other words, if a country generates 1EX/month of ECBDFs and another country generates 5EX/month, it is not necessarily the case that the second country can extract five times more value from ECBDFs compared to the first one. This

29 These secondary benefits were: brand loyalty and prestige; cloud services innovation and introduction of new services; confidence in forecasts for enterprise cloud services market growth; easier recruitment of best talents; economies of scale and cost leadership; enhanced publicity due to market leadership; geographical coverage and services distribution; knowledge of purchasing decisions of consumer base; understanding enterprise cloud service use by country, enterprise type and sector.

is because the value that enterprises can extract from cloud services depends on the type of business activities they perform on the cloud and not necessarily on the volume of data flows triggered by that use.

This is why the conceptual framework presented in this section and material parts of the methodology adopted to estimate the economic value of ECBDFs are different but complementary to the framework and the methodologies used to estimate the volume and location of ECBDFs above. Indeed, this framework starts from existing empirical research[30] that estimates the GVA of **cloud services** (but not of ECBDFs specifically) to enterprises that use those services, and attempts to find a way to estimate (by isolating) the intrinsic value of ECBDFs as a proportion of the value created by cloud services for enterprises that use these services in different sectors and countries.

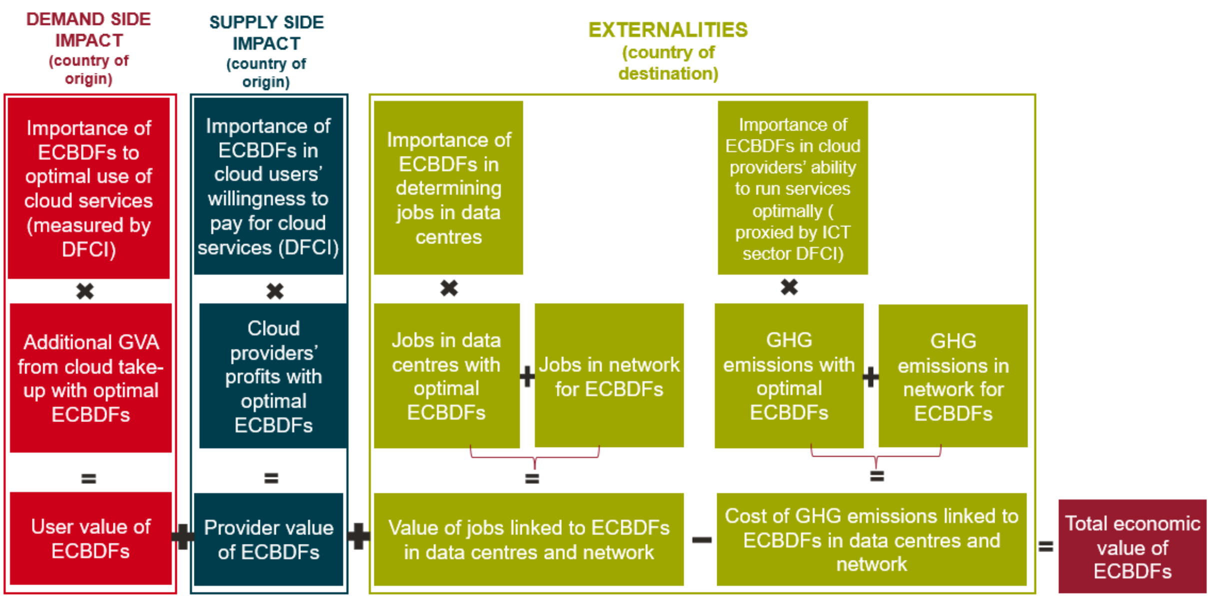
ii. Overall approach

Our framework considers a **hypothetical scenario in which enterprises still use cloud services but ECBDFs are limited or constrained for some reason** (e.g. limits in volume/quantity to frequency/speed, to geography and to the type of data flowing). By holding the quantity and quality of cloud services constant, this approach attempts to isolate the role that ECBDFs play in driving economic value. For example, if a consultancy firm like Frontier Economics normally generates €1m (in terms of the value it can add to the economy) from its unrestricted use of cloud services, but can only extract €0.7m in a scenario in which ECBDFs are constrained in some way, this means that the value that can be conceptually attributed to ECBDFs from the perspective of Frontier Economics is €0.3m.

As shown in Figure 2.5 below, we conceptualise and estimate the economic value of ECBDFs from the perspective of three different economic entities: the enterprises that use cloud services (**demand-side** or **user perspective**), the providers of cloud services (**supply-side** or **provider perspective**), and the wider economy/society (**externalities**). In microeconomic terms, these impacts can be associated with the concepts of consumer surplus, producer surplus and externalities. As explained in more detail in the following subsections, demand-side and supply-side impacts occur in the country of origin of ECBDFs (i.e. where the enterprise using the cloud services that trigger ECBDFs is located), while externalities occur in the country of destination (i.e. where the main and edge data centres of cloud providers are located, which can sometimes be the same as the country of origin if the enterprise uses a provider with a data centre in the same country).

30 Gal et al. (2019). https://www.oecd-ilibrary.org/economics/digitalisation-and-productivity-in-search-of-the-holy-grail-firm-level-empirical-evidence-from-eu-countries_5080f4b6-en

Figure 2.5 Graphical summary of methodology adopted to estimate economic value of ECBDFs[31]



In order to disentangle the value of ECBDFs from the intertwined value of cloud services, we developed a novel indicator called the Data Flows Criticality Index (DFCI).

The DFCI is a composite index that reflects the extent to which the activities based on the use of cloud services by enterprises in a given sector and country are dependent on ECBDFs (e.g. data analytics in the mobility sector). We use this index as a proxy for the proportion of the value that these enterprises extract from using cloud services that can be attributed to ECBDFs.

The DFCI is a key component of our methodology and a novel addition to the existing evidence base. We estimate the DFCI using data from Eurostat on three drivers that increase the importance of ECBDFs to an enterprise's ability to derive value from its use of cloud services in its key activities and operations:

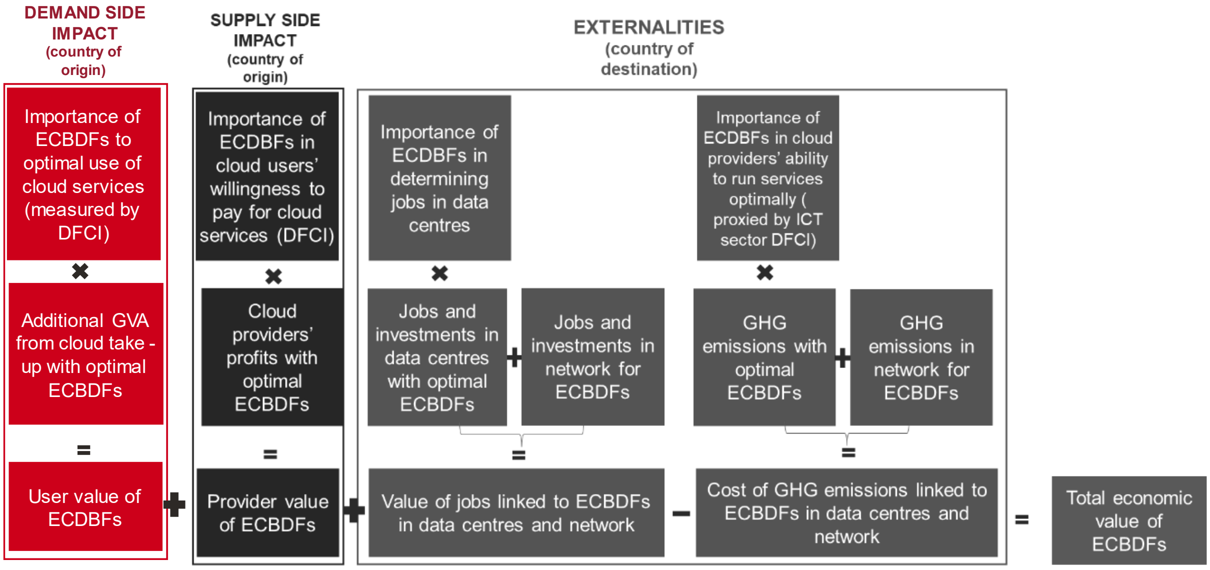
1. **Optimal use of cloud-based enterprise capabilities:** the extent to which the enterprise uses cloud capabilities that require a necessary minimum volume of ECBDFs to be used efficiently. This includes, for example, the use of AI, Big Data analysis, and Internet of Things (IoT) technologies;
2. **Access to customers:** the extent to which the enterprise requires ECBDFs to provide its goods or services to customers via cloud services; and
3. **Security:** the extent to which the enterprise requires ECBDFs to design/benefit from resilient cloud architectures and redundant data storage to secure its internal operations.

These drivers were identified as relevant through our literature review on the cloud sector and through the engagement between the Frontier team and the DG CNECT team in the course of the project.

[31] DFCI is the Data Flows Criticality Index: a novel indicator developed to isolate the economic value of ECBDFs in the total value of cloud services, described in more detail in the remainder of this chapter.

Estimated values of the DFCI across countries and sectors are presented in Chapter 3.b. Further detail on the construction, calculation and application of the DFCI is provided in the third section of the methodological note accompanying this report.[32]

iii. Economic value from the user perspective (demand-side)



Our approach to estimating value from the perspective of users (i.e. in our study, by users we mean enterprises that use cloud services) is based on three main steps. We summarise these steps below, with a fuller explanation provided in the methodology note.

First, we estimate the **value that is realised by enterprises** using cloud services (measured as additional Gross Value Added generated by these enterprises **as a result of their cloud use**.[33] For brevity, we describe this below as "value of cloud services to users". We estimate the value of cloud-services for each country-sector in Europe (e.g. Spanish Manufacturing). We then add up the country-sector values to calculate the total value of cloud services to cloud-using enterprises in each country in Europe.

To do this, we:

- Identify the total GVA generated in each country-sector in a given year (e.g. 2023), using data from Eurostat. For example, the GVA generated by enterprises in the Spanish manufacturing sector in 2023 was around €15bn.

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32 In summary, the DFCI is a composite index that we use to approximate the importance of ECBDFs to the optimal use of cloud services (and therefore, to users' willingness to pay for cloud services) and the importance of ECBDFs in cloud providers' ability to run their services optimally. To compute the DFCI, we collect and aggregate a set of eight indicators that measure the extent to which enterprises in each country-sector rely on ECBDFs. We use several indicators for each of the three drivers above (access to customers, optimal use of cloud-based capabilities, security) because it is not possible to measure each driver precisely with a single indicator. Instead, we use several indicators for each driver, so that the overall value of the DFCI is not overly reliant on any individual indicator.

33 We use GVA because this is typically the preferred measure of economic output at sector level. GVA is equal to GDP minus taxes plus subsidies. However, taxes and subsidies are often measured at the whole economy level rather than by sector. Therefore, data on economic output by sector typically uses GVA as a measure of output rather than GDP. Moreover, GVA is preferred to other metrics such as gross output or gross sales, as GVA accounts for the double-counting that may occur when including intermediate inputs in economic analyses. Summing up GVA for all sectors in a country provides a good proxy for the country's gross domestic product (GDP).

- estimate the part of this total country-sector GVA coming from ***enterprises using cloud services*** ("cloud-using GVA"). To do this, we multiply the total country-sector GVA (step 1) by the proportion of enterprises in that country-sector that use cloud (step 2). For example, 30% of enterprises in the Spanish manufacturing sector uses cloud services in 2023. Therefore, we estiamate that in 2023, the GVA generated by Spanish manufacturing cloud-using enterprises ("cloud-using GVA" in Spanish Manufacturing) was 30% * €20bn = €4.5bn.

- multiply "cloud-using GVA" for each country-sector by a "cloud attribution parameter" which also varies by country-sector. The cloud attribution parameter allows to estimating the proportion of "cloud-using GVA" that can be specifically attributed to cloud services (i.e. "**cloud-attributed GVA**"). This parameter is calculated departing from evidence from an existing study (Gal et al., 2019), which allows estimating the average percentage point increase in an enterprise's annual Multi-Factor Productivity (MFP) growth rate that results from a given percentage point increase in cloud uptake in that enterprise's country-sector. For example, assume that in the case of Spanish Manufacturing the cloud attribution parameter is 2.7%. In this example, the cloud-attributed GVA in the Spanish manufacturing sector would be around €4.5bn * 2.7% = €120m.

Second, we attempt to isolate the proportion of cloud service value that can be attributed to ECBDFs from the total value of cloud services as a whole (measured in terms of GVA). Clearly, it is never going to be truly possible to completely disentangle the value of the cloud service from the value of the flow because the two are intrinsically intertwined (without the cloud service there is no flow, and without the flow enterprises extract no value from cloud services). Instead, we attempt to find a way of proxying the circumstances in which ECBDFs represent more or less significant portions of the value of the cloud service to enterprises. In other words, the value of ECBDFs is conceptualised as intrinsic to the value of cloud services to enterprises: i.e. a proportion of the value of the cloud service is driven by ECBDFs.

Conceptually, we do this by considering a hypothetical scenario in which enterprises still use cloud services but ECBDFs are limited or constrained.

If, in this restricted hypothetical scenario, the GVA generated by enterprises that use cloud services (that can be attributed specifically to the use of cloud services) is the same (or very similar) to the GVA with unlimited flows, then the "intrinsic" value of ECBDFs in the total value of cloud services to enterprises is zero (or very limited).

If, on the other hand, **GVA diminishes in this restricted scenario, then the relative value of ECBDFs in the value of cloud services to enterprises is higher**. The larger the decline in GVA that is experienced when flows are reduced, the higher the relative value of ECBDFs in the value of cloud services to enterprises.

To recall the example made above, if cloud-usong enterprises in a given country-sector (like Spanish manfuacturing) normally extract €120m (in terms of GVA) from their unrestricted use of cloud services but can only extract €60m in a scenario in which ECBDFs are constrained in some way, this means that the value that can be conceptually attributed to ECBDFs from the perspective of the Spanish manufacturing sector is €120m - €60m = €60m.

In practical terms, to estimate by how much value can be attributed to ECBDFs, we use the DFCI described earlier in this section. For example, in the case of Spanish manufacturing, a DFCI value of 50% would indicate that 50% of the additional GVA extracted by cloud-using Spanish manufacturing firms through their cloud use can be attributed to ECBDFs.

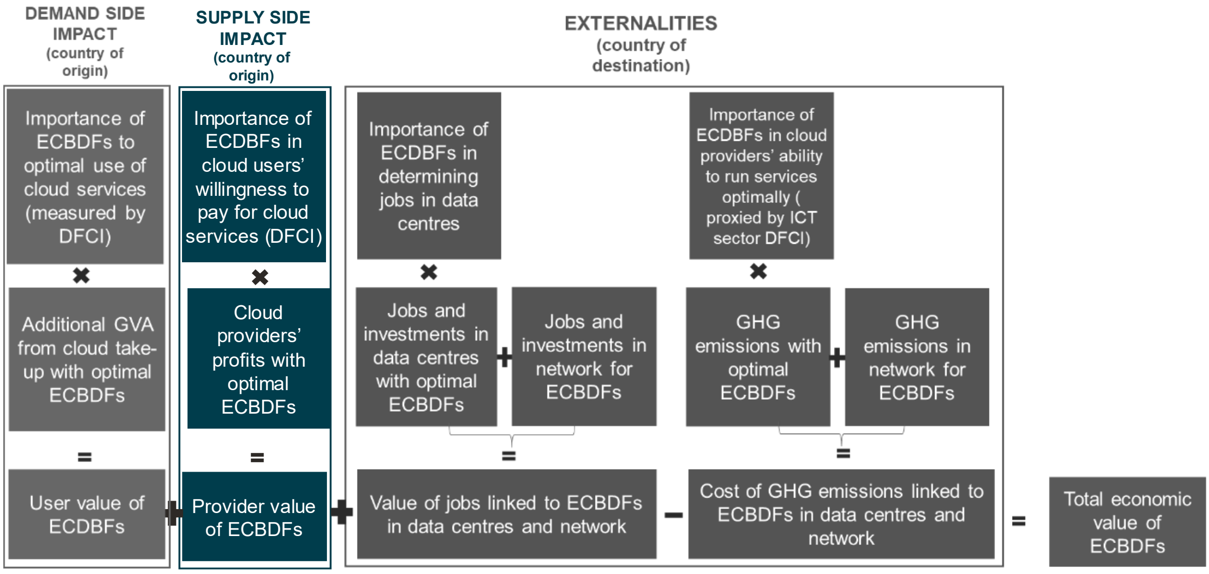
Figure 2.6 Graphical summary of demand-side impact

Third, we combine the two steps described above and estimate the demand-side economic value of ECBDFs by: multiplying our estimate of cloud-attributed GVA at country-sector level and the country-sector values of the DFCI. For example, in the case of Spanish Manufacturing, we multiply the €120m cloud-attributed GVA estimated at step 1 by the 50% DFCI estimated at step 2. The resulting estimate of the value of ECBDFs to cloud-using enterprises in the Spanish Manufacturing sector is 50% * €120m = €60m.

A practical example of demand-side value

- Let us take the example of two European enterprises. The first enterprise is a large Spanish manufacturing enterprise (SPAMA), which uses cloud services provided by cloud provider 1 (CP1) for its CRM platform (to manage existing and potential clients' information). The second enterprise is a small Belgian investment enterprise (BELFIN), which uses cloud services provided by CP2 for its machine learning (ML) algorithm which predicts future gas prices to speculate on the market.
- In the factual, they both send ECBDFs to CP1's and CP2's data centres located in France. SPAMA extracts €5m of GVA from these services and BELFIN extracts €10m. This is the economic value of cloud services to these firms. But what portion of this value might meaningfully be attributed to ECBDFs?
- To answer this question, we consider a hypothetical scenario where there is a limit/constraint on the ECBDFs triggered by SPAMA and BELFIN. For example, the ECBDFs they trigger are capped at 1 TB/month.
- In this hypothetical scenario, SPAMA can access customer data less frequently and the GVA it can extract from the CRM cloud platform decreases to €4.5m. The decline is small because the data activities that SPAMA performs on the cloud (e.g., commercial staff accessing list of clients on laptops/tablets) does not require high-scale ECBDFs. In the same scenario, BELFIN cannot reach the size needed for its trading algorithm to work well and therefore the GVA it extracts from the cloud service with limited ECBDFs is only €1m. The decline is big because BELFIN does not have many other options to run its algorithm with fewer data flows.
- So using this illustrative example, the value of ECBDFs to SPAMA is €0.5m, while the value of ECBDFs to BELFIN is €9m. This illustrative example can be scaled up to the entire economy, which comprises a variety of firms, some like SPAMA (which can replicate cloud services with fewer ECBDFs), some like BELFIN (which cannot replicate cloud services with fewer ECBDFs) and many others in between the two.
- The DFCI is a composite index that we use to approximate the importance of ECBDFs to the optimal use of cloud services (and, therefore, to users' willingness to pay for cloud services) in cloud providers' ability to run their services/activities optimally. Applied to this example, it is a number that indicates what proportion of enterprises in the Spanish manufacturing sector are like BELFIN (they rely critically on cloud data flows) and what proportion are like SPAMA (they do not rely critically on cloud data flows).

iv. Economic value from the perspective of providers (supply-side)



The conceptual framework discussed in the previous subsection can also be applied to estimate the economic value of ECBDFs from the perspective of providers (i.e. supply-side or provider-side value).

From a microeconomic perspective, the economic value of cloud services to cloud providers can be approximated using the profit generated by the provision of such services (i.e. any revenue over and above what is required to cover the costs of offering the service).[34]

Conceptually, in line with the approach described on the demand side, we attempt to isolate the value of ECBDFs from the perspective of cloud providers by using a hypothetical scenario in which providers still sell cloud services but ECBDFs are limited or constrained (a limit to the total amount of ECBDFs, on their frequency, or on their geographical origin/destination or on the type of data that flows). This constraint is an exogenous shock and there is no other change between the status quo and the hypothetical scenario except for the changes that result from the constraint on ECBDFs.

If, in this hypothetical counterfactual scenario, the profits generated by cloud providers are the same (or very similar) to the profits generated with unlimited flows, then the relative value of ECBDFs in driving profits is zero (or very limited). If, on the other hand, profits diminish in this restricted scenario, then the relative value of ECBDFs in profits is material.

In this framework, the extent to which ECBDFs drive profits depends on the use that enterprises make of cloud services and on how much value they can extract from these with more or fewer ECBDFs. This is why the provider-side dimension of value is strictly linked to the user-side dimension (i.e. the losses in profits in a scenario with limited ECBDFs are directly linked to the losses in GVA experienced by cloud users in the same scenario). This is also why we use the same DFCI applied in the demand-side value calculation to estimate the proportion

34 The reason why this conceptual framework focuses on profits and not on revenues from a supply-side perspective is that revenues represent a transfer of resources from the consumer (i.e. the enterprise using the cloud service) to the producer (i.e. the provider selling the same service). Conversely, profits represent genuine added value to the economy from the perspective of the provider. Indeed, microeconomic theory suggests that producers' surplus can be approximated as the profits made by producers in a given market.

of supply-side value attributable to ECBDFs (as described in the paragraphs below in more detail).

A practical example of provider-side value

- Let us look at the same example discussed above from a supply-side perspective. CP1 provides CRM cloud services to SPAMA (Spain) and cloud services to BELFIN (Belgium). CP1 makes €1m of profits from the SPAMA contract and €5m from the BELFIN contract. This is the economic value of cloud services to CP1. But what portion of this value might meaningfully be attributed to ECBDFs?
- To answer this question, we consider a hypothetical scenario where there is a limit or constraint on the ECBDFs organised by CP1. For example, ECBDFs are capped to 1TB/month.
- In this hypothetical scenario, CP1 experiences a relatively small impact on its profits of €0.1m as SPAMA is willing to pay slightly less for its cloud-based CRM service than before. In contrast, BELFIN extracts a lot less value from its machine learning algorithm and so is willing to pay much less for its cloud services with a bigger resulting impact on CP1 profits of €2.5m.
- Using this illustrative example, the value of ECBDFs to CP1 is €2.6m, reflecting the value of ECBDFs to enterprises served by CP1. This illustrative example can be scaled up to the entire cloud industry, which sells a variety of services to enterprises, some like the CRM sold to SPAMA (which is less reliant on ECBDFs), some like the ML service sold to BELFIN (which is more dependent on ECBDFs) and many others in between the two.
- The DFCI mentioned above aims to estimate where each country-sector pair sits in the spectrum between SPAMA and BELFIN.
- By comparing this example with the equivalent one presented in the previous section, it clearly emerges that there is no double-counting between the approaches used to estimate the user-side and the provider-side value of ECBDFs.
- Indeed, in the illustrative example provided in the user-side section above, the value of ECBDFs to SPAMA was €0.5m, while the value of ECBDFs to BELFIN was €9m. On the user's side, this value is driven by the GVA that both firms can extract from the cloud services. On the provider's side, the value is driven by the change in profits that can be made by selling cloud services to both enterprises in the counterfactual scenario.

We use the DFCI to isolate the proportion of providers' revenues (and therefore profits) that are attributable to ECBDFs. The reason why the DFCI is also used on the supply side of our framework is because, as shown in Figure 2.7 below, in a reasonably competitive market, the value that providers can extract from ECBDFs is directly linked to the value that users (their customers) can extract from these flows. Indeed, in a counterfactual scenario where ECBDFs were artificially restricted, enterprises that use cloud services would be able to add less value to the economy and therefore would be willing to pay less for cloud services. In turn, this would reduce the cloud providers' profits by a magnitude similar to the decline in GVA experienced on the demand side.[35]

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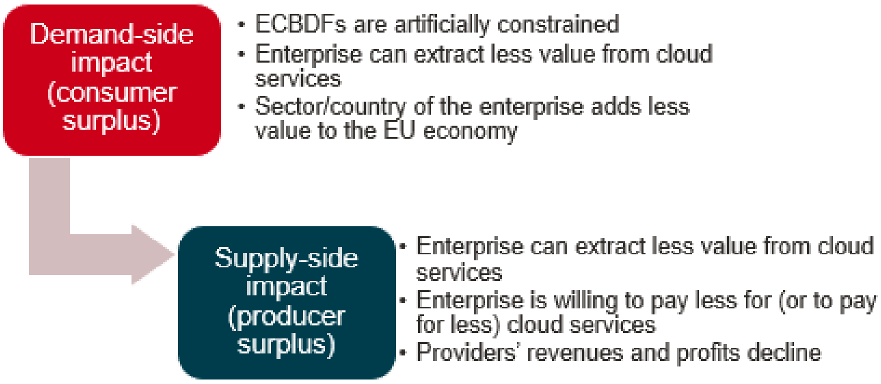
[35] In principle, we could use data on the impact of changes in the quality of cloud services, broadly defined (which would decrease as a result of constrained ECBDFs) on the demand for cloud services, but such data is not available.

We assume that this hypothetical loss of profits occurs in the same country where the enterprise using cloud services is located. This is because what changes in the counterfactual described above is the willingness to pay for cloud services by the enterprises that trigger the ECBDFs. In other words, SPAMA in the illustrative example above will be willing to pay less for cloud services with constrained ECBDFs, and therefore the Spanish subsidiary of CP1 will be able to generate lower profits. Even in the absence of a real subsidiary, the impact of constrained ECBDFs in Spain would be on CP1's ability to generate profits in Spain (i.e. from selling services to Spanish customers).

Figure 2.7 Causal link between demand-side and supply-side value of ECBDFs

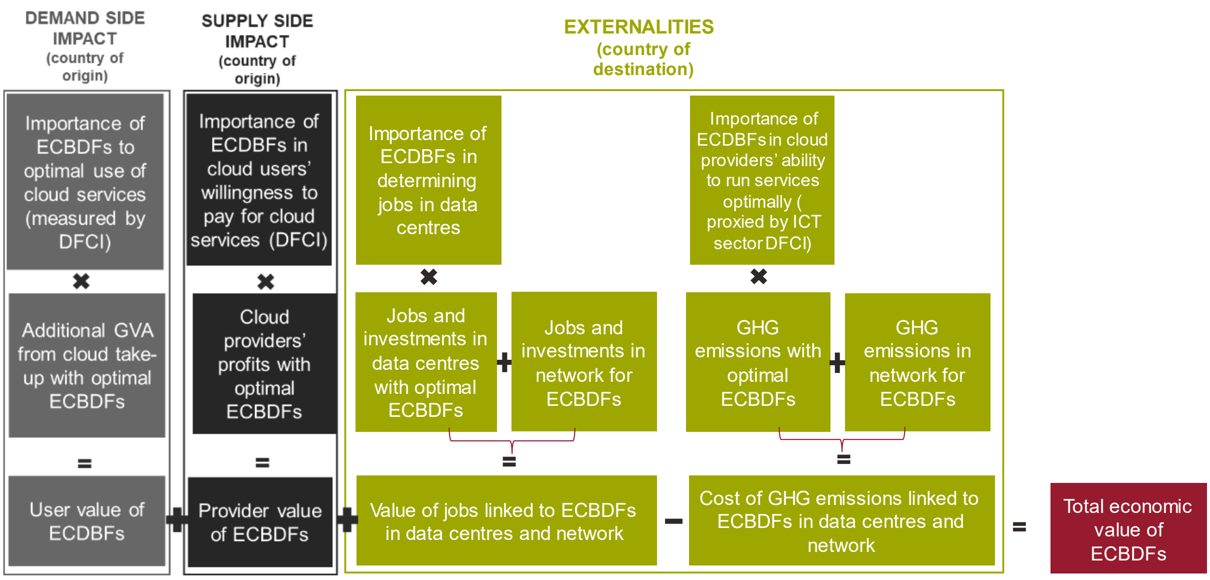


The second section of the methodological note provides more details on how this DFCI was constructed and calculated and how it is applied in practice in our calculations.

In extreme synthesis, in line with what has been done on the demand side, the supply-side economic value of ECBDFs is calculated by:

- Estimating the profits generated by cloud providers in different countries; and
- Mutiplying that value by the DFCI estimated for each country-sector pair, in order to isolate the proportion of profits attributable to ECBDFs.

v. Economic value from the perspective of society (externalities)



We have seen that ECBDFs have value for enterprises which consume them and for cloud providers which sell cloud services. However, besides the economic players that generate ECBDFs (i.e. users and providers of cloud services), the ECBDFs also impact the areas and the economies where the infrastructure needed to generate these flows is located. This infrastructure includes the data centres to which ECBDFs flow and the infrastructure needed to connect them (e.g. network, cables, exchange stations, servers and switches) to the origin of the flow (enterprise locations). Indeed, there is evidence[36] which shows that data flows have an impact on the areas where data centres and the connecting infrastructure are built, in terms of:

- GHG emissions (i.e. environmental impact)[37]; and
- Direct, indirect and induced job creation (i.e. local economic impact).

Once again, the main challenge of this analysis is the need to separate the externalities generated by cloud services in general from those triggered specifically by ECBDFs.

We attempt to do so by considering two mechanisms through which ECBDFs generate externalities (i.e. local economic impacts and GHG emissions) in the country of destination:

- By flowing through **connecting infrastructure** to the country of destination (i.e. through cables, exchange stations, servers and switches); and
- By being stored or processed in the **data centres** of the country of destination.

With regard to the first mechanism, we assume that **all the emissions and the jobs generated by ECBDFs as they flow through connecting infrastructure are attributable to ECBDFs**.[38] In practical terms, to implement this approach, we multiply: i) the volume of ECBDFs that flow to cloud data centres (including edge) in a given country by ii) empirical estimates of the jobs and emissions per TB that ECBDFs generate in the connecting infrastructure. These estimates are drawn from existing literature and our sources are described in detail in Section 2.3 of the methodological note accompanying this report.

For the second mechanism (ECBDFs stored or processed in the data centres of the country of destination), we recognise that the local jobs and GHG emissions associated with cloud data centres cannot all be attributed to ECBDFs. As a result:

- As a first step, we estimate the externalities generated by multiplying the volume of ECBDFs (in TB) that flow to data centres for a given country by the number of jobs and GHG emissions per TB of data stored in a data centre. In line with the externalities generated in the connecting infrastructure, the per TB impacts are estimated using existing academic literature on the subject.**Error! Bookmark not defined.**
- We multiply the result of the first step by the **DFCI of the information and communication technologies (ICT) sector** in the country under analysis, in order to isolate the proportion of these externalities that can be attributed to ECBDFs. The reason why we use the DFCI of the ICT sector and not the whole-economy DFCI is

[36] This evidence is described in Section 2.3 of the methodological note.

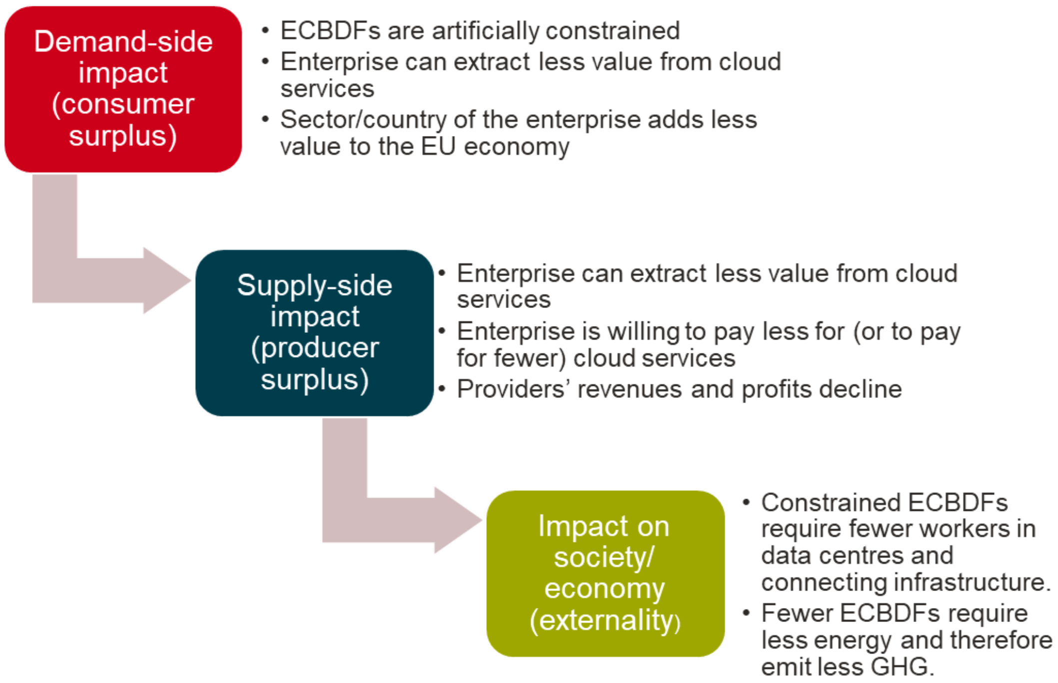
[37] The environmental impact measured in tonnes of CO_2e can be converted to € and subtracted from the positive economic values calculated in the previous sections. The reason why this dimension of economic value needs to be subtracted is that this is the only aspect where value increases in a counterfactual where ECBDFs are artificially constrained (fewer data flows, less energy consumed, fewer emissions).

[38] This does not mean that we attribute all the externalities generated by the network to ECBDFs. It means that, if the network can process 1TB per hour and we estimate that the ECBDFs that flow through that network are 1TB per day, 1/24 (as there are 24 hours in a day) of the externalities produced by the network can be attributed to ECBDFs.

because the externalities will occur exclusively in the cloud sector (for which the closest NACE sector is ICT), while the user-side and provider-side dimensions of value described above occur in all sectors.

In simple terms, we assume that only a proportion of the jobs and emissions generated by the data centre destinations of ECBDFs are attributable to ECBDFs.

Figure 2.8 Link between demand-side, supply-side value and externalities of ECBDFs



The final step in our calculation is to estimate the value measured in euros of each job and of each CO2-equivalent (CO2e) tonne of GHG emissions that result from ECBDFs. This also allows us to sum up the value of jobs and the value of GHG emissions and to obtain a total value of externalities. The methodological note provides more details on how these calculations and estimates are performed.

A practical example of externalities

- Let us look at the same example discussed above from the perspective of the wider economy/society. The fact that SPAMA and BELFIN use cloud services provided by CP1 and CP2 triggers ECBDFs from Spain and Belgium to the country where the nearest data centre of CP1 and CP2, respectively, is located.
- For illustrative purposes, let us assume that CP1 has a data centre in Spain and that the closest data centre to Belgium owned by CP2 is also in Spain. Let us also assume that SPAMA and BELFIN generate 100 TB of ECBDFs per month.
- From an economic perspective, not only do these flows have a value for SPAMA and BELFIN (as described in the demand section) as well as for CP1 and CP2 (as described in the supply

section), they also have a value from the perspective of the wider society of the country of destination.

  - Indeed, these flows will need a connecting infrastructure to reach Spain (e.g. cables, networks, switches). This infrastructure needs to be built and maintained, creating jobs (which generate a positive impact on the local economy), but this infrastructure also consumes energy (which generates a negative impact on the environment in terms of GHG emissions). Once the number of jobs and emissions generated by 100 TB of data flowing in the network is estimated, we assume that all the jobs and the emissions caused by 100 TB of ECBDFs in the network can be attributed to ECBDFs.

- In addition, as mentioned above, ECBDFs are stored and processed at data centres which have to be built and maintained, creating jobs (which generate a positive impact on the local economy). They also consume energy (which generates a negative impact on the environment in terms of GHG emissions). While not all of the externalities generated by data centres can be attributed to ECBDFs, a proportion of them needs to be accounted for when estimating the economic value of ECBDFs, and we estimate this proportion using the DFCI of the ICT sector (to which cloud providers belong).
- For example, if secondary estimates indicate that 100 TB of ECBDFs requires two jobs in the data centre to which the data flows and the DFCI of the ICT sector is 50%, we would estimate that the 1TB of ECBDF generated by SPAMA has generated a positive externality of one data centre job in Spain. This job is valued at the annual GVA produced by the worker, e.g. €50,000.
- Similarly, if secondary estimates indicate that on average 100 TB of ECBDFs requires 30,000 KWh for its storage and processing in a cloud data centre, and that this involves an environmental cost valued at €352, we would attribute to the ECBDFs 0.5 * 352 = €176 to the ECBDFs generated by SPAMA.

3. Main results and conclusions on volume of ECBDFs

a. Current volume of ECBDFs

We estimate the volume of ECBDFs generated by enterprises in Europe (specifically, the EU, EFTA and the UK), split by country, by NACE sector and by enterprise size band (measured in terms of number of employees).

We estimate both the volume of these flows that stay within Europe – including intra-country flows and flows to other European countries – and the volume of these flows that leave Europe to flow to other regions.

The results presented in this chapter include estimates for the year 2023 (the latest year in which Eurostat collected data on cloud adoption statistics). None of the figures presented in this section of the report account for ECBDFs triggered by the consumption of on-premises cloud services, apart from those presented in the dedicated Section (3.d.). Instead, the results focus on ECBDFs triggered by the consumption of public cloud services.

In addition, Section e. of this chapter presents estimated ECBDFs in 2016, 2018, 2020 and 2023, to provide a historical perspective over the period since the adoption (2016) and entry into force (2018) of the Free Flow of Non-Personal Data Regulation and after, in order to support the upcoming evaluation of this Regulation.

Section f. presents forecasts for 2024 (the year of publication of this report), 2025, 2030 (end year of the *Digital Decade Policy Programme*) and 2035. The online data visualisation tool includes estimates for every year between 2016 and 2036.

The figures and the results included in this chapter show the most relevant outputs of our analysis, while a more granular and complete set of results is presented in the online data visualisation tool.

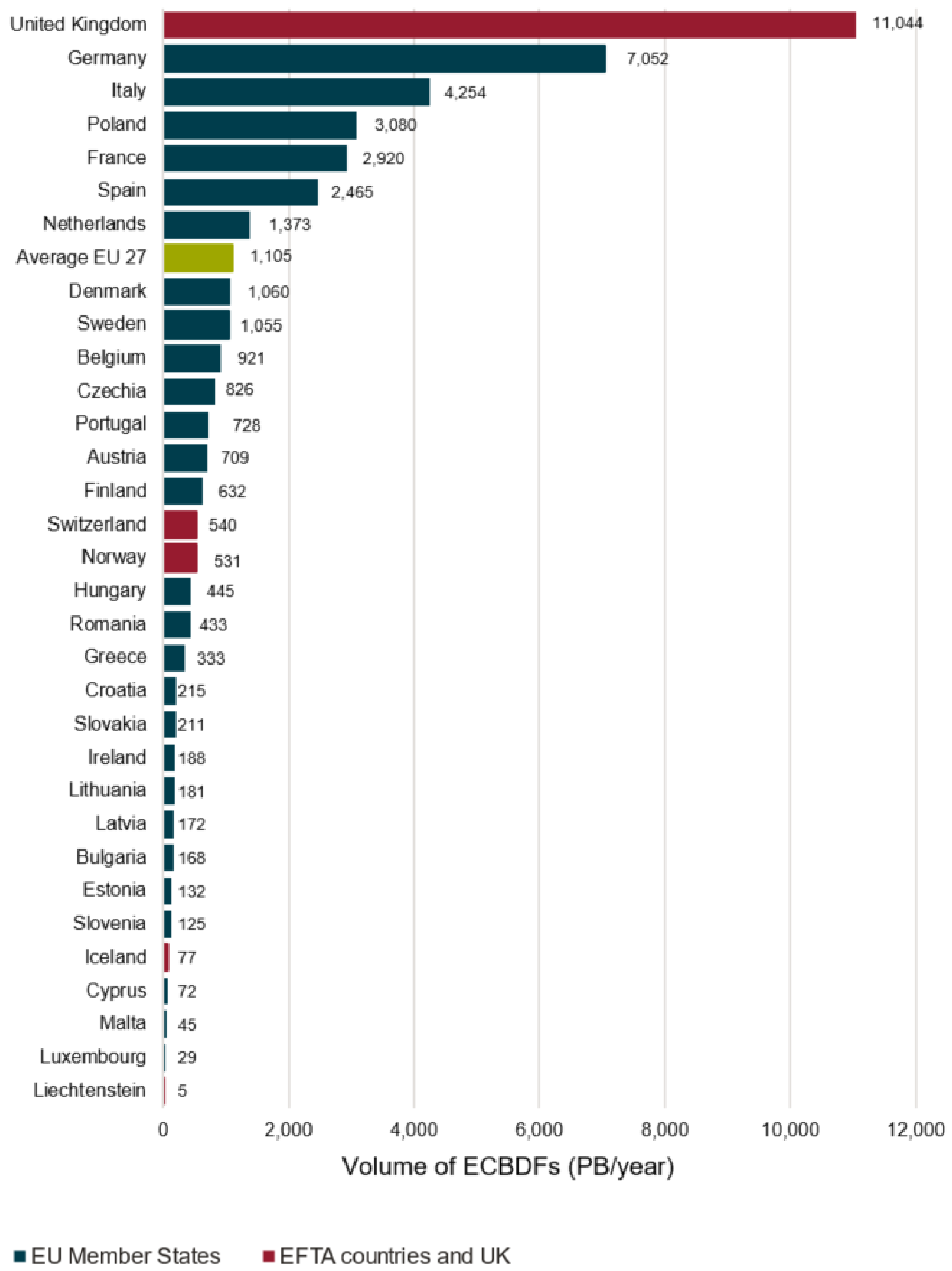
When relevant, some of the tables and charts that follow are coloured according to whether the country is in the EU (blue), in EFTA or the UK (red), or represents the EU average (green). They are ordered in descending order of magnitude of volume.

All figures are presented in petabytes (PB) per year. One petabyte equals 1,024 terabytes (TB), and 1,048,576 gigabytes (GB).

As shown in Figure 3.1 below, we estimate that, in 2023, enterprises that operated in the EU and used cloud services generated approximately **30,000 PB/year of ECBDFs**. This is around 200 times the data storage capacity of the Internet Archive, the world's largest library of internet content, which archives over 860 million web pages.[39] Enterprises that operate in EFTA countries (excluding the UK), generated around **1,200 PB/year of ECBDFs in 2023**. For the UK, this was **11,000 PB/year of ECBDFs**. For the total EU, EFTA and the UK, this was **42,000 PB/year of ECBDFs in 2023**.

[39] As of 10 January 2024. Source: https://archive.org/~tracey/mrtg/du.htmlhttps://archive.org/~tracey/mrtg/du.html, retrieved on 10/1/2024 at 10.36 CET.

Figure 3.1 ECBDFs generated by each European country (i.e. country of origin) in 2023



In terms of countries that generate the highest volume of ECBDFs, our findings are in line with previous studies and highlight that the top five countries are **the UK, Germany, Italy, Poland, and France** (which together generated approximately 28,000 PB/year in total in 2023) closely followed by **Spain** (2,465 PB/year).

Conversely, **Liechtenstein, Luxembourg, Malta, Cyprus and Iceland** are estimated to generate fewer ECBDFs (less than 230 PB/year in total in 2023). The ordering of countries remains broadly consistent over the forecast period presented later in this report.

As described in more detail in Chapter 1.f above and in Section 1 of the methodology note, variation in country-level volume for a given year is driven by three key inputs:

- The number of employees/workers in each sector;
- The proportion of enterprises that use cloud services in each sector;[40] and
- The volume of internet traffic per employee generated in each country.

In general, there is greater cross-country variation in the number of workers compared to the other two factors, meaning that this factor is generally the most important for determining the volume of ECBFs.

Larger countries with more workers (Germany, France, Italy, Spain and the UK) are likely to generate higher volumes of ECBDFs, because the occasionally higher cloud uptake or internet use per employee in smaller countries is not sufficient to “compensate” for their lower numbers of workers.

A slight deviation to this rule, however, can be seen by taking a closer look at the top two countries – the UK and Germany. Although Germany has a larger population and greater number of employees than the UK, the UK has a larger average cloud uptake rate across NACE sectors as well as a higher level of internet traffic per employee than Germany. This results in a larger estimated volume of ECBDFs in the UK.

One of the fundamental assumptions of our calculations is that ECBDFs flow to the nearest main or edge data centre owned by the cloud provider used by the enterprise that generates the flow. This means that countries where the largest providers of cloud services have one or more data centres will see more ECBDFs flowing to cloud facilities located within the same country than the one in which flows are triggered, as shown in Figure 3.2 below.

We estimate that, in 2023, approximately **half (15,700 PB/year of ECBDFs)** of the 30,000 PB/year of ECBDFs generated by enterprises that operate in the **EU** and use cloud services **stayed within their origin countries, one-third (9,000 PB/year) flowed to other European countries (EU + EFTA + UK), and one-sixth (5,000 PB/year) flowed to non-European countries**.

For EFTA (excluding UK), this was around 640 PB/year of ECBDFs staying within the country of origin (out of 1,150 generated in EFTA countries), 345 flowing to other European countries (EU + EFTA + UK), and 200 to non-European countries. For EU + EFTA + UK, this was 24,800 PB/year of ECBDFs staying within the country of origin, 10,000 flowing to other European countries, and 7,100 to non-European countries.[41]

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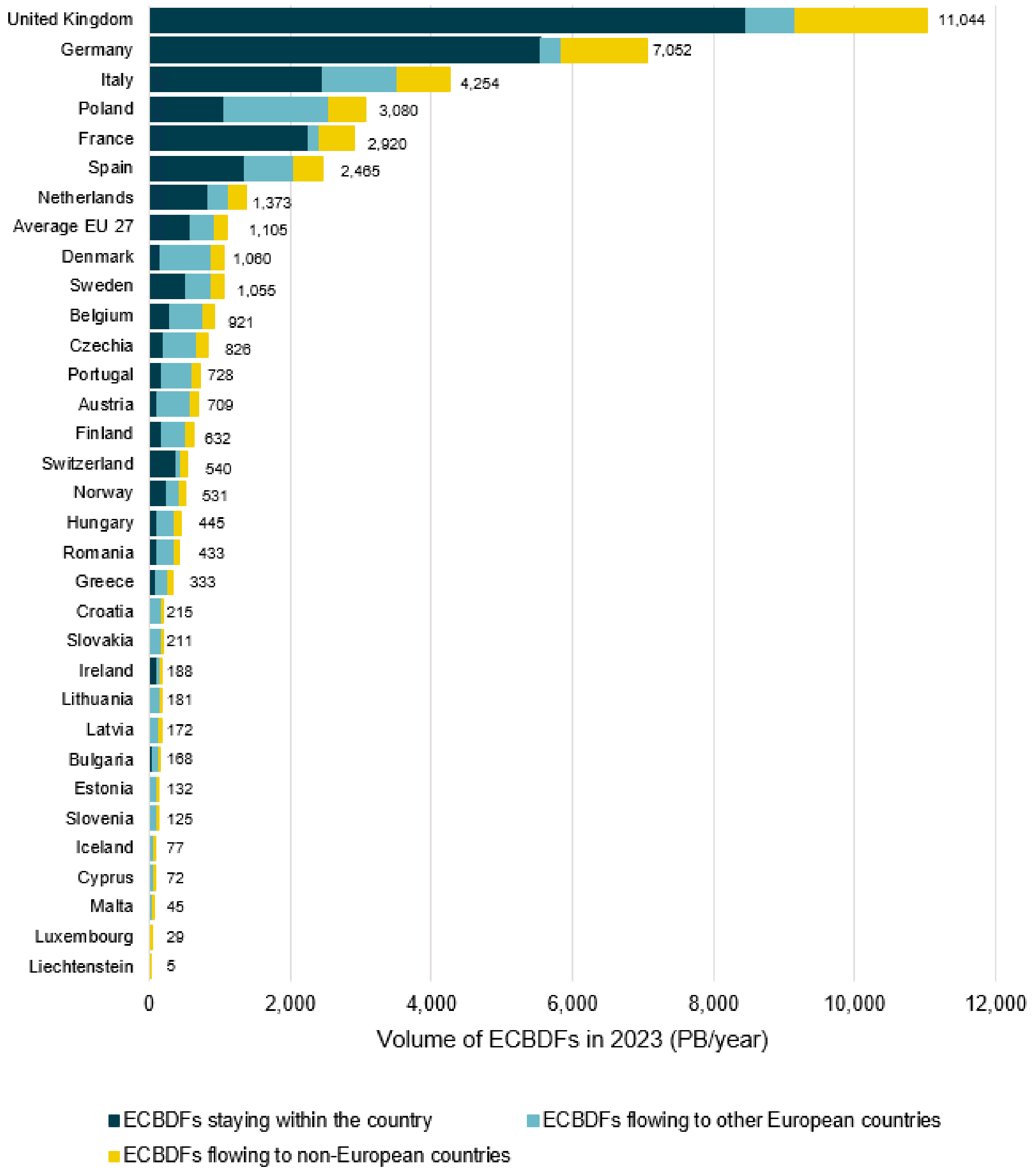
[40] We use the latest version of Eurostat data covering the year 2023 for this variable. We note that Eurostat shows a break in the time series for France and Sweden in 2023, which we take at face value.

[41] Note: these figures may not add up exactly to the total ECBDF volumes presented earlier in this chapter due to rounding.

Figure 3.2 ECBDFs generated by each European country, broken down by destination in 2023 (country of destination)



As shown in the chart above, in the five largest countries in Europe by population and GDP (Germany, UK, France, Italy and Poland), a significant proportion (between 35% and 78%) of ECBDFs are expected to flow to cloud facilities located within the same country. In general, countries with larger volumes of ECBDFs tend to have a larger proportion of ECBDFs that remain in the country. This is because major cloud providers (see Table 3.1 below for more details on the mapping of cloud and edge infrastructures) tend to have main and/or edge cloud data centres located in these countries.

Switzerland and Ireland are exceptions to this rule. Despite their medium-sized economies, and despite a low average volume of ECBDFs generated, they both host a range of main and edge data centres from the major cloud providers, including from the largest two providers, AWS and Microsoft Azure. As a result, they also have a significant proportion of flows that stay within the country (64% and 73% respectively).

Conversely, smaller countries do not frequently host main cloud or edge data centres and therefore generate more flows going to other European (i.e. EU, EFTA and UK) countries (i.e. where the nearest centres are located).

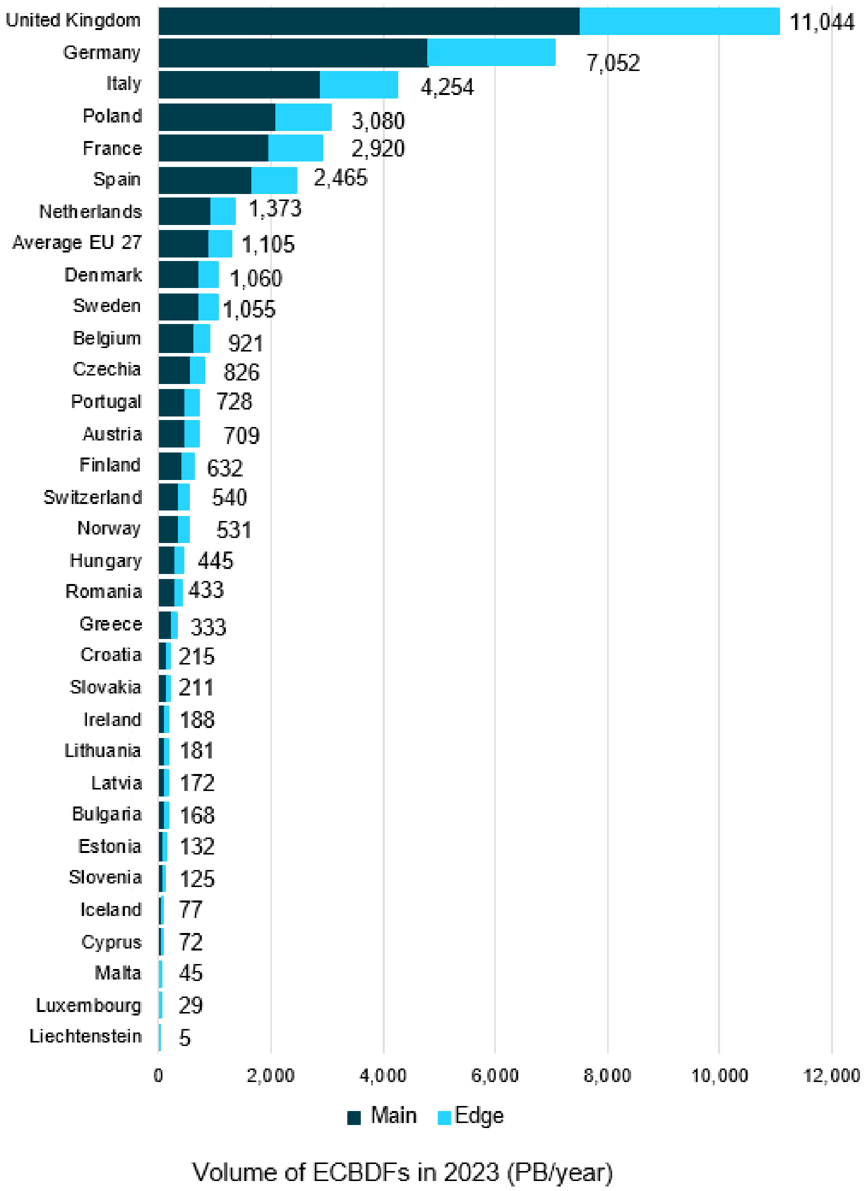
For example, based on our research, **Cyprus, Malta, Iceland, Estonia, Latvia, Liechtenstein, Lithuania, Luxembourg, Slovenia and Slovakia** do not appear to host a main or edge data centre of the top five providers analysed in this report. This is why no ECBDFs stay in these countries, and why they also receive no flow from neighbouring countries. In other words, all their ECBDFs are outflows.

Similarly, relatively small countries like **Croatia, Bulgaria, Hungary and Romania** appear to host only a few edge data centres. In these four countries, the percentage of ECBDFs that flow to cloud facilities located within their own country is estimated to be between 14% and 25%.

As shown in Figure 3.3 below, we estimate that, in 2023, for the EU approximately 20,300 PB/year of ECBDFs generated flowed to main data centres, and 9,500 PB/year flowed to edge data centres. For EFTA (excluding UK), this was 780 PB/year of ECBDFs to main data centres, and 370 PB/year to edge data centres. For the UK, this was 7,500 PB/year flowing to main data centres and 3,500 PB/year to edge data centres. For EU + EFTA + UK, this was 28,600 PB/year to main data centres, and 13,400 PB/year to edge data centres.

This is based on an assumption that, in 2023, 32% of ECBDFs flowed to edge data centres and the remaining proportion to main data centres. A more detailed explanation of this assumption (as well as of how the edge proportion is expected to increase over the period under analysis) can be found in Section 1.d of the methodological note.

Figure 3.3 ECBDFs that flowed to main and edge cloud centres in 2023



The mapping of main and edge data centres used to produce these estimates is summarised in Table 3.1 below and is based on publicly available sources extracted from the websites of the main cloud providers analysed in this report. More details on this mapping exercise are provided in Section 1.g of the methodological note, together with the mapping produced for smaller cloud providers (by market share) not included in the table below.[42] Both the smaller cloud providers and these large providers are used in our analysis. However, given their large market shares, the providers displayed below are most consequential to determining our final ECBDF volume estimates.

Table 3.1 Main and edge cloud data centre regions across the top five providers by market share in EU countries, EFTA and UK, 2023

42 See Table 2.12 in the methodological note.

Cloud Service Providers	AWS	Microsoft Azure	Google Cloud	Oracle	IBM	Total
Belgium	2E	M*+2E	M+2E	0	0	M+M*+6E
Bulgaria	3E	2E	E	0	0	6E
Czechia	E+E*	E	E	0	0	3E+E*
Denmark	4E	M*	E	N/A	0	M*+5E
Germany	M+39E+2E*	M+7E	2M+4E+E*	0	0	7M+51E+3E*
Ireland	M+3E	M+2E	E	0	0	2M+6E
Greece	E+E*	M*+E	E	0	0	M*+3E+E*
Spain	M+12E+E*	M*+2E	M+2E	2M	0	4M+M*+16E+E*
France	M+17E	M+6E	M+2E	2M	M	6M+25E
Croatia	E	0	E	0	0	2E
Italy	M+16E	M*+3E	2M+3E	M	M	5M+M*
Cyprus	0	0	0	0	0	0
Hungary	E	E	E	0	0	3E
Malta	0	0	0	0	0	0
Netherlands	5E+E*	M	M+2E	M	E	3M+8E+E*
Austria	3E+E*	M*	E	0	0	M*+E*+4E
Poland	6E	M*+E	M+E	0	0	M+M*+8E
Portugal	E+E*	E	E	0	0	3E+E*
Romania	E	E	E	0	0	3E
Finland	5E	M*+E	M+2E	0	0	M+M*+8E
Sweden	M+4E	M*+2E	E	M	0	2M+M*+7E
Iceland	0	0	0	0	0	0
Norway	2E+E*	M+2E	E	0	0	M+5E+E*
Switzerland	M+2E	M+2E	M+2E	M	0	4M+6E
United Kingdom	M+30E	2M+6E	M+2E	4M	M	9M+41E
Estonia	0	0	0	0	0	0
Latvia	0	0	0	0	0	0
Liechtenstein	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0
Slovakia	0	0	0	0	0	0
Total	8M+162E+9E*	8M+9M*+43E	12M+31E+E*	14M	4M+E	46M+9M*+239E+10E*

Sources: First-party sources, for main data centres: AWS, Microsoft Azure, Google Cloud, Oracle (1), Oracle (2), Oracle (3), IBM. Edge data centre sources (and categorisation) are shown in Annex B of the methodological note

*Note: M = Main, E = Edge. *Data centre planned or under construction.*
Zeroes within the tables mean that there are no main or edge data centres for this country-provider combination

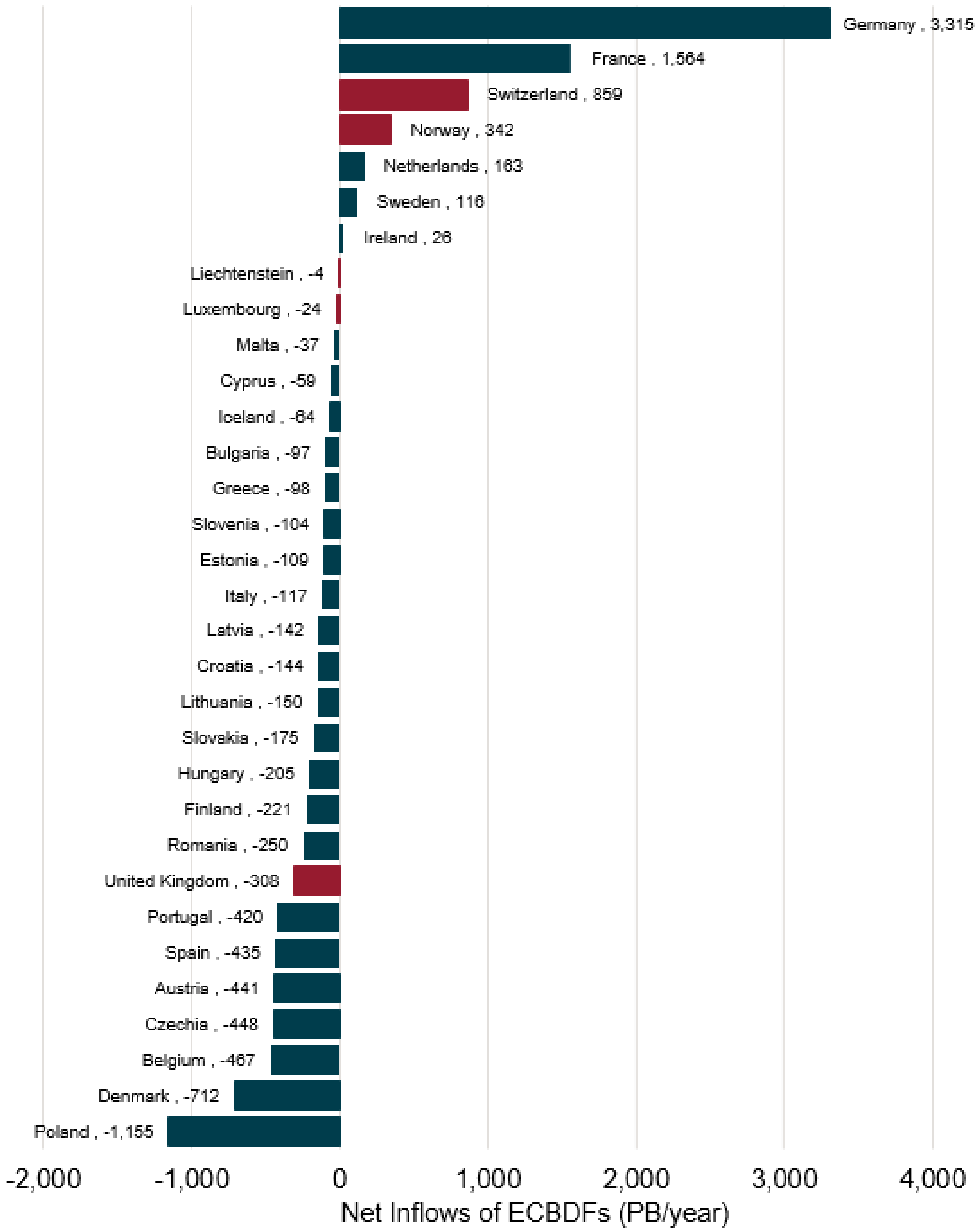
The mapping of main and edge data centres summarised above is the main driver of the net inflows of ECBDFs estimated for each country. By net inflows we mean the difference between the ECBDF inflows (ECBDFs that flow to a given country from other European countries) and ECBDF outflows (ECBDFs that leave the same given country to other European countries). This measure does not account for the proportion of ECBDFs that flow from non-European countries because we do not have information on the ECBDFs that flow from non-European countries to European countries (which would be needed to have a comprehensive overview of net inflows).

More specifically, below we present two measures of inflows: firstly, net inflows, which exclude from the analysis flows that stay in the country (Figure 3.4); secondly, the net ECBDFs processed within the country (i.e. net inflows plus flows that stay in the origin country) in Figure 3.5.

The two measures estimated and presented in Figures 3.4 and 3.5 are clearly different and capture different aspects of the role played by each country in relation to ECBDFs. If one is interested in the extent to which a specific country is a net receiver or sender of EBCDFs, the measure presented in Figure 3.4 appears to be more fit for purpose. Conversely, if the focus is on whether the country processes a greater volume of ECBDFs within its borders compared to the volume it sends out to other countries, then it would be best to use the indicator presented in Figure 3.5.[43] Overall, the two measures can be seen as complementary.

[43] Note that, for these figures, we do not present results for the EU average or EU/EFTA aggregates, because conceptually we model flows as moving in and out of specific countries based on geographical location. As such, the relationship between the EU and EFTA would not be informative beyond picking up what is happening for the largest countries in either grouping. To present net flows for these aggregates would risk confusion as ECBDFs do not "flow" out of the aggregates but out of their constituents. Although the same is true to an extent for ECBDF generation (ECBDFs are generated within each constituent country), we believe that the way ECBDFs "sum up" for the aggregates is conceptually more intuitive and informative, as it relates directly to each aggregate's size.

Figure 3.4 Net inflows of ECBDFs for each European country in 2023



As shown in Figure 3.4 above, the countries that receive the biggest net inflows of ECBDFs are large countries where many data centres are located (with the top five **being Germany, France, Switzerland, Norway and the Netherlands**). This result is not surprising in light of the assumption that ECBDFs generated by an enterprise located in a country where cloud providers do not have a (main or edge) data centre will flow to the nearest country where the cloud provider does have a (main or edge) data centre.[44]

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[44] Flows on a country-to-country basis are presented in Table 3.2 below.

A full breakdown of neighbouring countries is provided in Section 1.g of the methodological note. The note also explains fully the methodology behind our allocation of flows to destination countries.

The smallest net inflows of ECBDFs (i.e. the largest negative numbers in the figure above) are observed in medium-sized countries where the largest cloud providers are not found to have a main or edge data centre (e.g. **Denmark, Czechia, Austria and Poland**). **Belgium** also sits in the bottom five as, despite hosting a Google data centre, it does not currently host any other main data centres operated by the other main cloud providers.

Geography plays a significant role in these results. **The top three countries – Germany, France and Switzerland** – all have a large number of border countries. Data flows into Germany, France and Switzerland in cases where these bordering countries do not have a data centre for a given provider. Comparatively, the **UK's** location as an island, and to the west of continental Europe without European countries bordering it to the east, means it has low inflows relative to its size, resulting in its outflows dominating inflows.

Specifically, the reason for this is that there are not many European countries where, for any point along their border, the UK is the closest country (only Norway, Denmark, France and Ireland). It is only when these countries do not have a (main or edge) data centre for a given provider (and the UK does) that ECBDFs flow in (aside from cases where none of their neighbours do either, in which case the UK may be a receiver of ECBDFs).

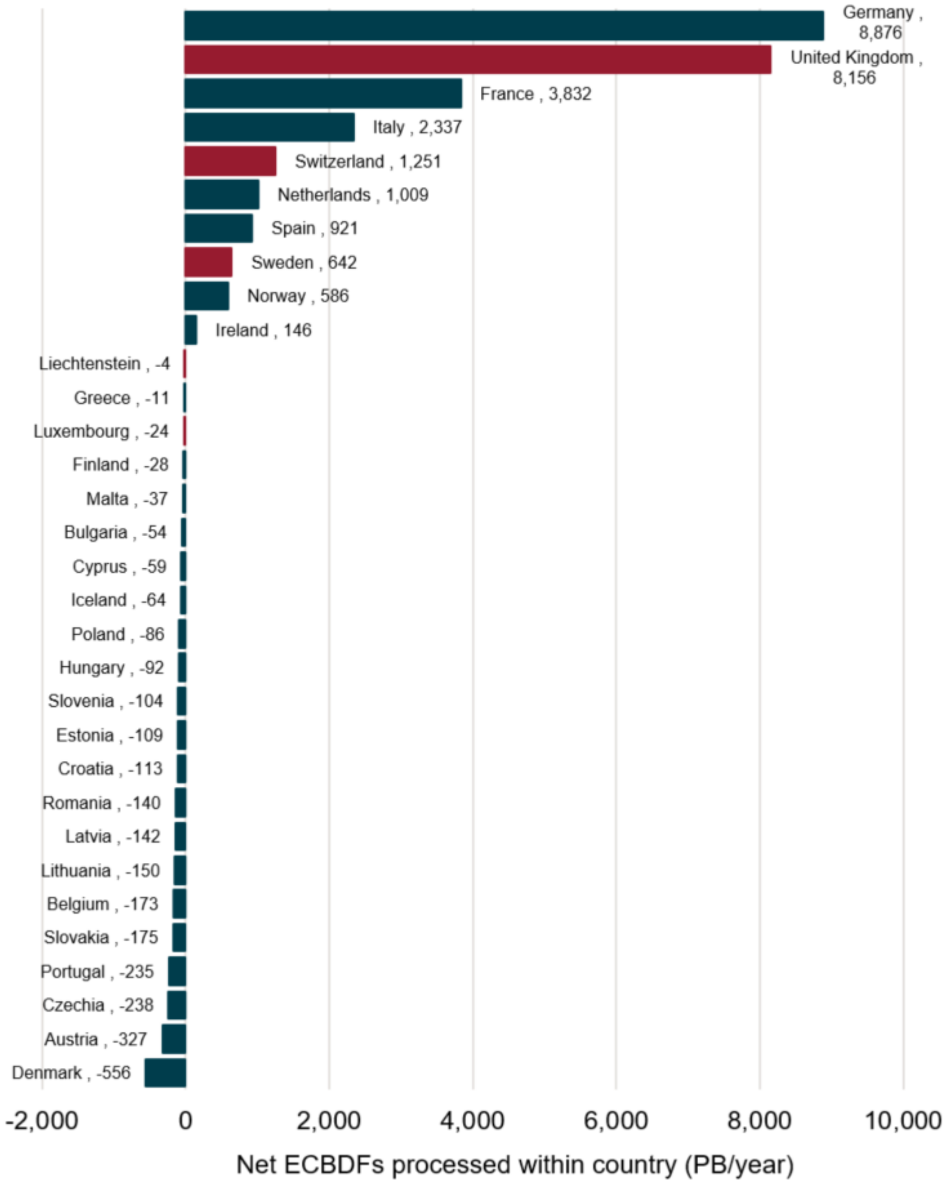
ECBDFs tend to only flow to the UK in rare cases where the UK has a (main or edge) data centre for a given provider but many other countries do not. The same is not the case for other countries such as Germany which have a large number of bordering countries, which, by definition, are closest to Germany for a given point along their border.

For example, there are a large number of bordering countries to Germany (e.g. France, Switzerland, Belgium, Poland, Denmark, the Netherlands, and more), resulting in many cases where ECBDFs flow in. This figure does not account for the volume of ECBDFs that stay in the country, of which the UK has a large volume.

Indeed, when we look at the volume of net ECBDFs processed in each European country (in Figure 3.5 below) which include net inflows plus ECBDFs flowing within each country, we see that the UK has the second most in Europe, only behind Germany. The figure below shows that the total volume of net ECBDFs processed in the UK in 2023 was 8,155 PB/year. Like the UK, Italy and Spain are also countries that process a large volume of ECBDFs within their borders (as shown in Figure 3.5 below), although there are more ECBDFs leaving these countries compared to ECBDFs arriving in the country from abroad (as shown in the earlier Figure 3.4).

Overall, the top five and bottom five countries shown in this figure are, respectively, the UK, Germany, France, Italy and Switzerland, and Slovakia, Portugal, Czechia, Austria and Denmark.

Figure 3.5 ECBDFs processed in the country minus ECBDFs that flowed out (i.e. net inflows of ECBDFs + ECBDFs staying in the country) for each European country in 2023



Finally, Table 3.2 below shows the specific direction of flows on a country-by-country basis for 2023.[45] The columns represent the origin country, and the rows represent the destination country. Blue cells where the origin and destination country are the same represent when ECBDFs remain in the country of origin. This is included in Figure 3.5 above as the "staying in the country" component (but is not accounted for, as explained, in Figure 3.4). These blue cells are represented graphically by the dark blue bars in Table 3.2.

The five largest cross-country flows in 2023 are: Poland to Germany (1,402 PB); Italy to France (511 PB); Italy to Switzerland (438 PB); Czechia to Germany (406 PB); and Netherlands to Germany (288 PB). Three of the five involve flows to Germany due to the number of data

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45 Blue cells indicate the volume of flows that stay in a country. The "total flowing to" column excludes flows that stay in the country.

centres in the country and the relative lack of such infrastructure in some of the neighbouring countries (Poland and Czechia); two of the five involve flows from Italy to two neighbouring countries (France and Switzerland). This picture is likely to change in the future as main data centres are built in Italy and Poland – further discussion of future flows is provided later in this chapter.

Overall, we estimate that, in 2023, around 53% of ECBDFs that originated in the EU stayed within the country of origin, with 30% flowing to other European countries and the remaining 17% to other regions. There is significant variation around this average. For example, 80% of the ECBDFs generated in Germany are estimated to have remained within Germany. On the other end of the spectrum, 100% of the ECBDFs generated by small countries like Cyprus, Latvia, Lithuania and Luxembourg are assumed to have flowed to other countries. This volatility is driven by the fact that most cloud providers have main cloud centres and edge facilities in large countries like Germany and France, while the small countries listed above do not appear to have such cloud facilities, which means that all ECBDFs are estimated to flow to other countries.

Table 3.2 Country-by-country direction of ECBDFs within Europe

	UK	DE	IT	PL	FR	ES	NL	DK	SE	BE	CZ	PT	AT	FI	CH	NO	HU	RO	EL	HR	SK	IE	LT	LV	BG	EE	SI	IS	CY	MT	LU	LI	
United Kingdom	8,463	-	-	-	12	21	-	209	-	-	-	6	-	-	-	84	-	-	-	-	-	27	-	-	-	-	-	36	-	-	-	-	8,859
Germany	170	5,562	72	1,402	70	21	288	259	62	188	406	6	170	33	18	16	99	86	39	25	42	3	26	26	19	19	15	1	8	5	10	0	9,168
Italy	152	97	2,453	21	25	34	4	15	7	13	11	10	93	4	13	7	52	37	106	82	20	3	2	2	51	1	51	1	23	26	0	0	3,414
Poland	-	30	23	1,069	5	-	1	-	7	-	42	-	32	9	-	-	16	38	3	2	33	-	61	21	6	2	1	-	1	-	-	-	1,401
France	107	79	511	21	2,268	580	1	-	-	178	6	171	5	-	24	-	3	3	7	4	1	2	1	-	1	-	3	-	1	2	10	0	3,988
Spain	-	-	23	-	16	1,356	-	-	-	-	-	216	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	-	-	1,611
Netherlands	166	86	-	21	-	-	846	20	15	92	6	-	9	9	-	11	3	3	2	1	1	2	2	2	1	2	0	1	0	-	-	-	1,303
Denmark	-	-	-	-	-	-	-	156	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	168
Sweden	-	-	-	-	-	-	-	117	525	-	-	-	-	147	-	65	-	-	-	-	-	-	40	55	-	43	-	-	-	-	-	-	992
Belgium	-	-	-	-	-	-	-	-	-	294	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	297
Czechia	-	-	-	-	-	-	-	-	-	-	209	-	13	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	238
Portugal	-	-	-	-	-	-	-	-	-	-	-	184	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	184
Austria	-	-	-	-	-	-	-	-	-	-	5	-	114	-	1	-	9	3	-	-	9	-	-	-	1	-	6	-	-	-	-	0	148
Finland	-	-	-	-	-	-	-	-	50	-	-	-	-	193	-	13	-	-	-	-	-	-	-	19	-	29	-	-	-	-	-	-	304
Switzerland	-	-	438	-	12	34	-	-	-	-	-	10	140	-	392	-	75	73	32	21	36	-	-	-	16	-	12	-	7	5	-	3	1,307
Norway	47	-	-	-	-	-	1	104	203	-	-	-	-	126	-	244	-	-	-	-	-	-	16	16	-	13	-	13	-	-	-	-	782
Hungary	-	-	-	-	-	-	-	-	-	-	-	-	13	-	-	-	113	-	-	12	15	-	-	-	-	-	11	-	-	-	-	-	165
Romania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110
Greece	-	-	11	21	16	-	-	-	7	-	-	-	-	4	-	-	-	6	87	1	1	-	1	1	2	1	-	-	19	-	-	-	178
Croatia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	4	-	-	-	-	-	35
Slovakia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120	-	-	-	-	-	1	-	-	-	-	182
Lithuania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Latvia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulgaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43	-	-	-	-	-	-	-	43
Estonia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slovenia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Luxembourg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Liechtenstein	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total originating from	9,167	5,854	3,531	2,556	2,424	2,046	1,139	879	876	765	686	604	588	524	448	441	369	360	276	178	175	156	150	142	140	109	104	64	59	37	24	4	34,876

b. ECBDFs that flow to other regions

This study adds to previous evidence on the volume of ECBDFs in Europe (the Tech4i2 and VVA studies) by estimating the volume of ECBDFs that flow to regions outside Europe.

We estimate that, in 2023, 17% of the total ECBDFs generated by enterprises operating in Europe flowed to regions outside Europe. This amounts to 7,143 PB/year of ECBDFs that flowed from Europe to other regions (Africa, North America, Asia and the Middle East), of which 5,070 PB flowed from EU countries and 2,073 flowed from EFTA and the UK.

As described in Section 2 of this report, our methodology for estimating the destination of European ECBDFs involves assuming that, of the ECBDFs that flow to main cloud data centres, 25% flow to cloud facilities located outside Europe (EU, EFTA and UK). This is based on existing market intelligence which indicates that 25% of internet traffic in Europe flows to other regions (TeleGeography). While this data refers to internet traffic in general and not to ECBDFs, it is the best source of data available to inform this specific assumption of the model.[46] Conversely, all ECBDFs that flow to edge facilities are assumed to stay within the region. The proportion of ECBDFs that flowed to main data centres in 2023 in Europe is 68% (hence 25% * 68% = 17% is our estimate of the proportion of ECBDFs that flowed to regions outside Europe). This proportion is expected to decrease between 2023 and 2035, while the proportion of ECBDFs that are assumed to flow to edge centres is expected to increase over the period under analysis.

Out of the 17% of ECBDFs that flow from Europe to other regions, approximately 22% are estimated to flow to North America, 16% to Africa, 37% to the Middle East and 25% to Asia. The resulting ECBDF volumes that flow to each of these regions from the EU and from EFTA and the UK is shown in Figure 3.6 below.

This calculation is based on public information published by TeleGeography on inter-regional bandwidth which takes into account the location and capacity of communications infrastructure, including submarine cables.[47] For example, data on international bandwidth shows that, of the total capacity that connects Europe to other regions (130,371), 22% (28,340) consists of inter-regional capacity between Europe and North America. Therefore, we assume that 22% of ECBDFs that leave Europe flow to North America. Further detail on this calculation and the assumptions it involves is provided in the first section of the methodological note.

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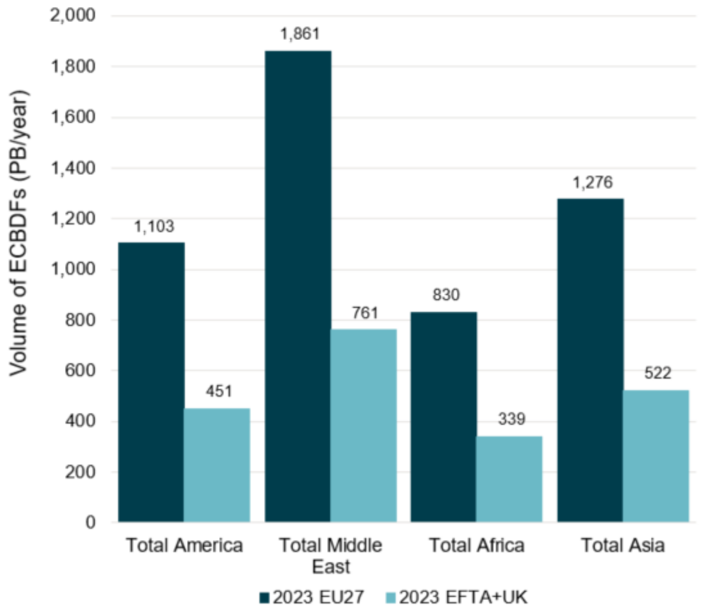
[46] This assumption is based on the publicly available Global Internet Map 2021 published by TeleGeography. https://global-internet-map-2021.telegeography.com/

[47] This is based on information on interregional internet bandwidth published by Telegeography as an annex to its Global Internet Map 2022: https://global-internet-map-2022.telegeography.com/

Figure 3.6 Breakdown of ECBDFs that flowed from Europe to other regions in 2023



Publicly available data on submarine cables and other forms of international communications infrastructure is available only at a continental level. As a result, the charts below show the same assumptions applied to every country under analysis (i.e. we do not make different assumptions for countries closer to the regions of destination – for example, Greece and the Middle East). In reality, data that flows to the Middle East is expected to flow mostly via France, Greece and Italy due to the location of the connecting infrastructure (mostly submarine cables).[48]

Similarly, data that flows to the USA and Canada is expected to flow outside of the region from France, Spain, Portugal, the UK, Iceland, Norway and Ireland, and data that flows to Africa is expected to use infrastructure located in Spain, Italy and France.

However, as the focus of this analysis is on enterprises that use cloud services in the country where they operate and trigger a cloud-based data flow from that country, we present the results broken down by the country where the data flow originates.

48 See the global map of submarine cables published yearly by TeleGeography: https://www.submarinecablemap.com/

Figure 3.7 ECBDFs that flowed to non-European regions in 2023

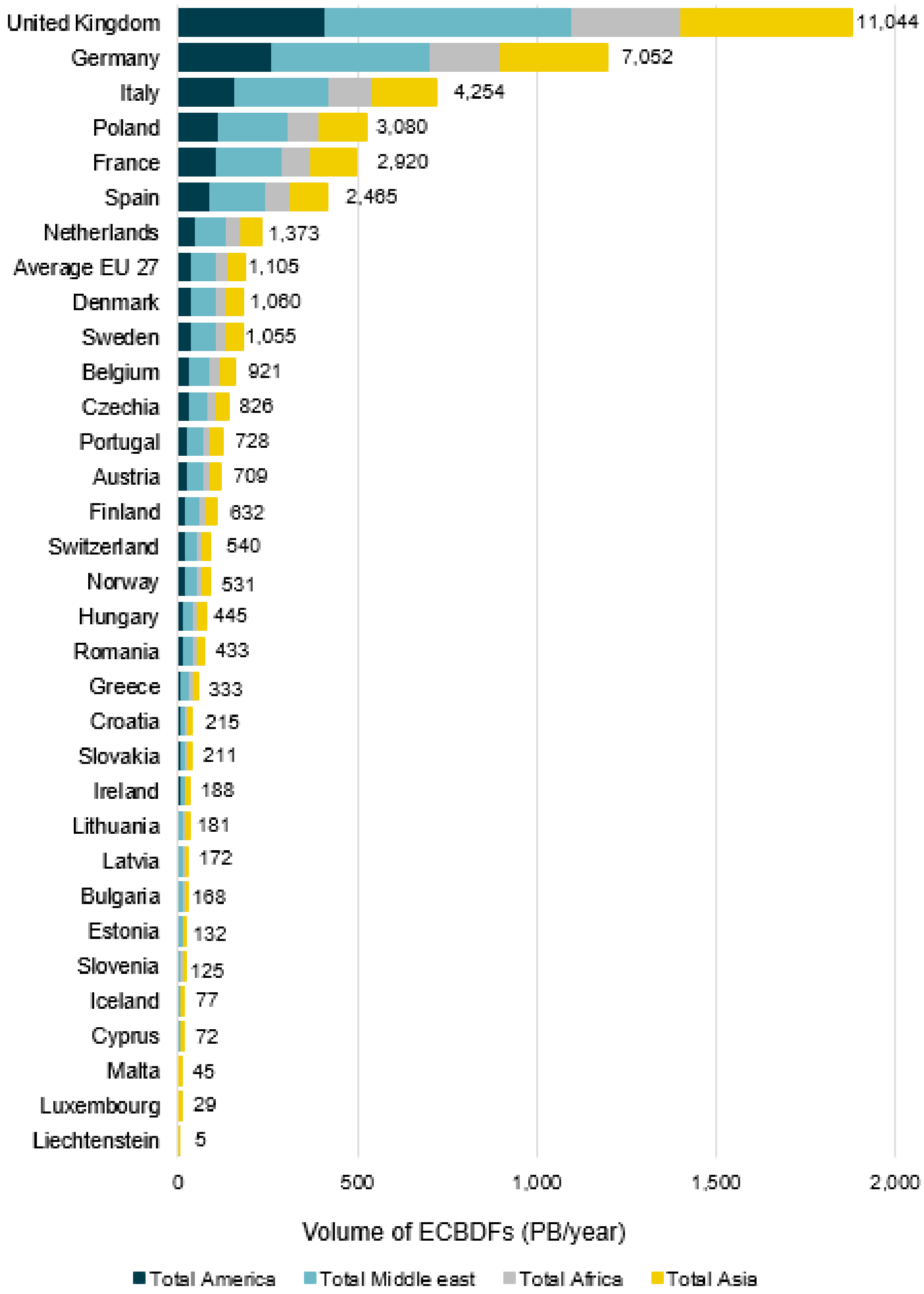


Table 3.3 below shows the volume of ECBDFs that flowed from the EU, EFTA and UK, and Europe as a whole to each country outside of Europe. The "top" destinations of extra-European ECBDFs within each region are:

- Israel and the UAE in the Middle East
- China and Japan in Asia
- The USA and Canada in North America
- South Africa in Africa

The individual countries that account for the largest amount of extra-EU ECBDFs (leftmost column in Table 3.3 below) are South Africa (821 PB/year, 3% of all EU ECBDFs in 2023), USA and Canada (with around 550 PB/year each, 1.85% of all EU ECBDFs in 2023), Israel

(530 PB/year, 1.78% of all EU ECBDFs in 2023) and UAE (466 PB/year, 1.6% of all EU ECBDFs in 2023).

Table 3.3 Breakdown of ECBDFs that flowed from Europe to other regions in 2023 (PB/year)

	EU	EFTA+UK	*Total Europe*
USA	552	226	778
Canada	552	226	778
Total North America	**1,103**	**451**	**1554**
Turkey	58	24	82
Israel	530	217	747
UAE	466	191	657
Bahrain	249	102	351
Qatar	252	103	355
Saudi Arabia	304	125	429
Total Middle East	**1,861**	**761**	**2622**
Egypt	9	4	13
South Africa	821	336	1157
Total Africa	**830**	**339**	**1169**
China	220	90	310
Japan	242	99	341
India	209	86	295
Indonesia	106	43	149
Taiwan	20	8	28
South Korea	209	86	295
Malaysia	3	1	4
Thailand	9	4	13
Singapore	258	106	364
Total Asia	**1,276**	**522**	**1798**
Total	**5,070**	**2,073**	**7143**

This “ranking” within each region is driven by the information obtained from publicly available sources on the location of main cloud data centres owned by the top cloud providers outside of Europe. This data is presented in Table 3.4 below.

As the same Europe-wide assumptions on the proportion of ECBDFs that flow to other regions are applied to all the European countries analysed, the “top” origins of these flows are the countries estimated to generate the largest volume of ECBDFs (**Germany, UK, France, Italy and Poland**). Conversely, the smallest flows to other regions are expected to come from **Liechtenstein, Iceland, Luxembourg, Malta and Cyprus**.

Table 3.4 Mapping of main data centres in non-European regions, 2023[49]

	AWS	Azure	Google	Oracle	IBM	SAP	DT	OVH	TIM	Orange	Ten-cent	Ali-baba	Hua-wei	Total
USA	6	9+1*	9	4	2	27	0	2	0	0	2	0	0	61

49 Note that these are all main data centres (not edge), as we consider all ECBDFs that flow to edge data centres to remain in Europe.

Canada	2	2	2	2	1	6	0	1	0	0	1	0	0	17
Total North America	**8**	**11**	**11**	**6**	**3**	**33**	**0**	**3**	**0**	**0**	**3**	**0**	**0**	**78**
Turkey	0	0	0	0	0	1	0	0	1	0	0	0	1	3
Israel	1	1	1	1	0	1	0	0	0	0	0	0	0	5
UAE	1	1	0	2	0	3	0	0	0	0	0	0	0	7
Bahrain	1	0	0	0	0	1	0	0	0	0	0	0	0	2
Qatar	0	1	1	0	0	1	0	0	0	0	0	0	0	3
Saudi Arabia	0	2	1	1	0	5	0	0	0	0	0	0	1	10
Total Middle East	**3**	**5**	**3**	**4**	**0**	**12**	**0**	**0**	**1**	**0**	**0**	**0**	**2**	**30**
Egypt	0	0	0	0	0	1	0	0	0	0	0	0	0	1
South Africa	1	2	0	1	0	5	0	0	0	0	0	0	1	10
Total Africa	**1**	**2**	**0**	**1**	**0**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**11**
China	3	5	1	0	0	5	0	0	0	0	7	1	9	31
Japan	2	2	2	2	1	4	0	0	0	0	1	0	0	14
India	2	2+1*	2	2	0	4	0	0	0	0	1	0	0	11
Indonesia	1	1*	1	0	0	1	0	0	0	0	1	0	1	5
Taiwan	0	1*	1	0	0	1	0	0	0	0	0	0	0	2
South Korea	1	1	1	2	0	1	0	0	0	0	1	0	0	7
Malaysia	0	1*	0	0	0	1	0	0	0	0	0	0	0	1
Thailand	0	0	0	0	0	0	0	0	0	0	1	0	1	2
Singapore	1	0	1	1	0	2	1	1	0	0	1	0	1	9
Total Asia	**10**	**10**	**9**	**7**	**1**	**19**	**1**	**1**	**0**	**0**	**13**	**1**	**12**	**82**
Total	**22**	**28**	**23**	**18**	**4**	**70**	**1**	**4**	**1**	**0**	**16**	**1**	**15**	**201**

Sources: First-party sources, for main data centres (edge and third-party sources cited above): AWS, Microsoft Azure, Google Cloud, Oracle (1), Oracle (2), Oracle (3), IBM, SAP, Deutsche Telekom (T-Systems), OVH, Telecom Italia, Orange (1), Orange (2), Orange (3), Tencent (including partner regions), Alibaba, Huawei

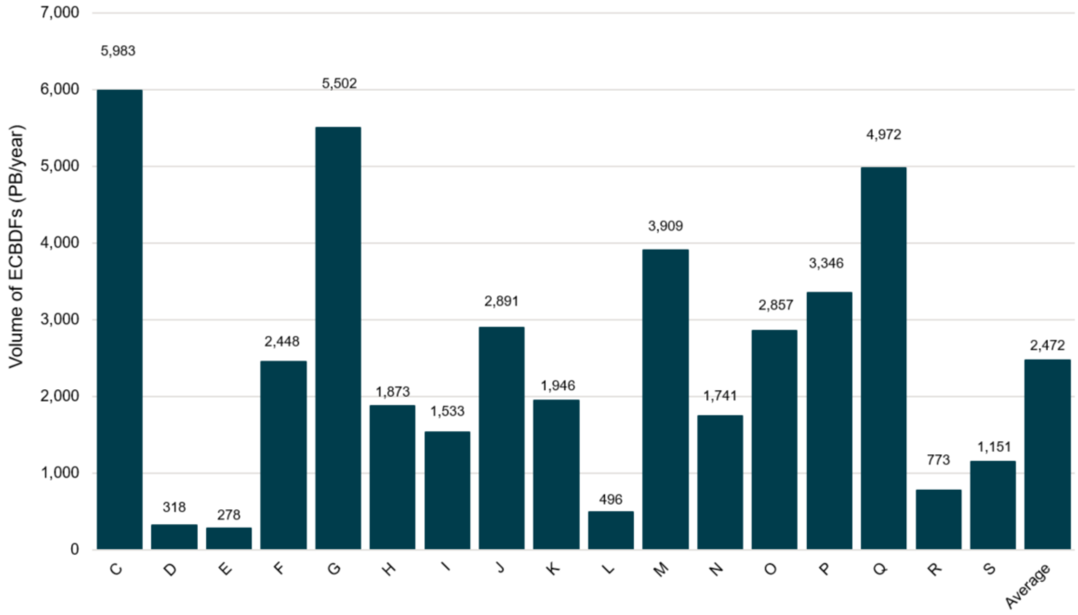
As shown in the table above, North America and Asia are the regions with the largest number of data centres. Unsurprisingly, Chinese providers like Tencent appear to have a disproportionate number of facilities in China, while the large American players have many cloud data centres in the USA. With regard to Africa, the providers that appear to have data centres in the region are AWS, Azure, SAP, Oracle, Telecom Italia and Huawei.

c. ECBDFs by sector and employee size band

This section briefly presents the other breakdowns generated by our estimates beyond the country breakdowns discussed above. The online data visualisation tool presents a vast variety of combinations of breakdown of volume of ECBDFs by country, NACE sector and enterprise size. In this section, we present the two most interesting insights of these estimates.

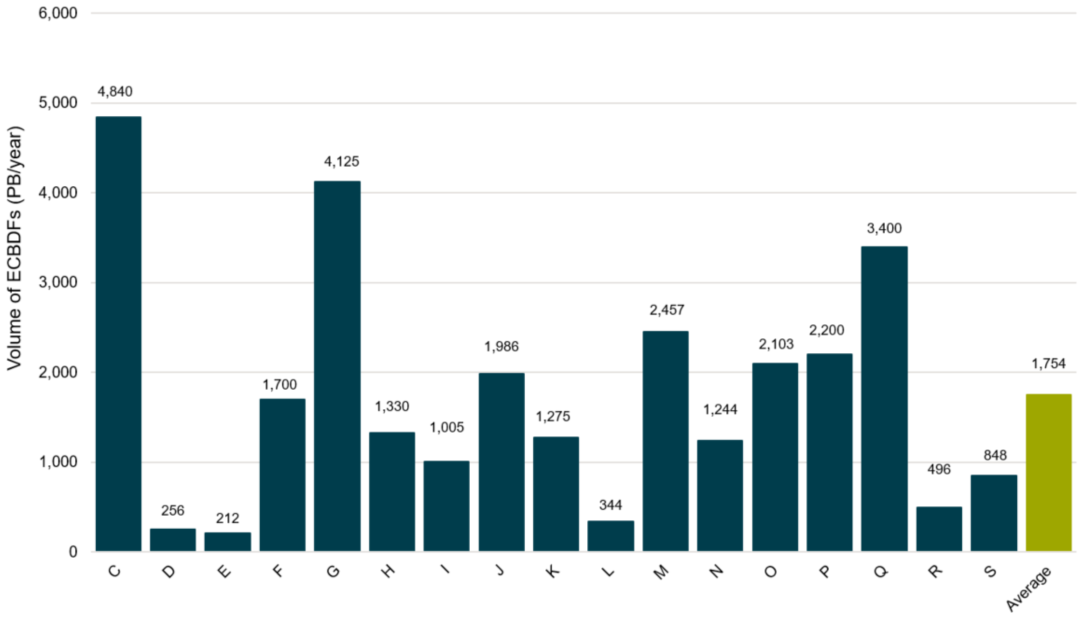
First, as shown in Figure 3.8 below, the three sectors that are expected to have generated the largest magnitudes of ECBDFs (in 2023) are **C: manufacturing, G: wholesale/retail and Q: human health & social work activities**. Sector J (information and communication) does not feature among the top five sectors by ECBDF volume due to its relatively smaller size (its GVA in 2023 across all European countries was only one-third of the GVA of the manufacturing sector, for example). Conversely, the smallest sectors in terms of ECBDF generation are **electricity, water supply, real estate and arts**. These trends are generally consistent across all years given the lack of significant variation on a sector-by-sector basis for employment and cloud uptake.

Figure 3.8 ECBDFs broken down by NACE sector 2023, EU + EFTA + UK



Note: C=Manufacturing; D=Electricity, Gas, Steam and Air Conditioning Supply; E=Water Supply; Sewerage, Waste Management and Remediation Activities; F=Construction; G=Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H=Transportation and Storage; I=Accommodation and Food Service Activities; J=Information and Communication; K=Financial and Insurance Activities; L=Real Estate Activities; M=Professional, Scientific and Technical Activities; N=Administrative and Support Service Activities; O= Public Administration and Defence; Compulsory Social Security; P=Education; Q=Human Health and Social Work Activities; R=Arts, Entertainment and Recreation; S=Other Service Activities. Sectors A (Agriculture, Forestry and Fishing) and B (Mining and Quarrying) are not included in the analysis as there is no data on cloud uptake available on Eurostat and none of the other sectors is sufficiently comparable to generate a proxy.

Figure 3.9 ECBDFs broken down by NACE sector 2023, EU



Note: C=Manufacturing; D=Electricity, Gas, Steam and Air Conditioning Supply; E=Water Supply; Sewerage, Waste Management and Remediation Activities; F=Construction; G=Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H=Transportation and Storage; I=Accommodation and Food Service Activities; J=Information and Communication; K=Financial and Insurance Activities; L=Real Estate Activities; M=Professional, Scientific and Technical Activities; N=Administrative and Support Service Activities; O=Public Administration and Defence; Compulsory Social Security;

P=Education; Q=Human Health and Social Work Activities; R=Arts, Entertainment and Recreation; S=Other Service Activities. Sectors A (Agriculture, Forestry and Fishing) and B (Mining and Quarrying) are not included in the analysis as there is no data on cloud uptake available on Eurostat and none of the other sectors is sufficiently comparable to generate a proxy.

Similarly to what we observe on a by-country basis, there is more cross-sector variation in the number of workers than in the proportion of enterprises that use cloud services. As a result, sectors with more workers will generally tend to generate more ECBDFs because the occasionally higher cloud uptake observed in smaller sectors is not sufficient to "compensate" for the lower number of workers.

Second, as outlined in Figure 3.10 below, large enterprises are estimated to contribute most significantly to the generation of ECBDFs in Europe. This is because these enterprises employ more workers by definition and are characterised by a higher uptake of cloud services compared to smaller enterprises.[50]

Please note that, as explained in Section 2 of the report, the estimates presented below are generated using cloud uptake by country and size band as one of the key inputs in our calculations, rather than cloud uptake by country-sector as for all other estimates of ECBDF volumes. As a result, there is a small difference between the total ECBDF volume across all size bands shown below and the total ECBDF volume reported earlier in this section.

[50] One limitation of our model is that we assume the same internet use per employee for all businesses in a given country, and do not split this out by sector. However, in some sectors, e.g. financial and insurance activities, employees may use more internet per employee than employees in other sectors, e.g. construction. And if a certain country's employment is more heavily weighted towards the former sector than the latter, this would increase ECBDFs in a way not accounted for in our modelling. Against this backdrop, in the absence of a credible data source that could solve this limitation, we use the assumption that internet use per employee is identical across all sectors.

Figure 3.10 ECBDFs in Europe (EU + EFTA + UK) broken down by enterprise size (number of employees size band) in 2023

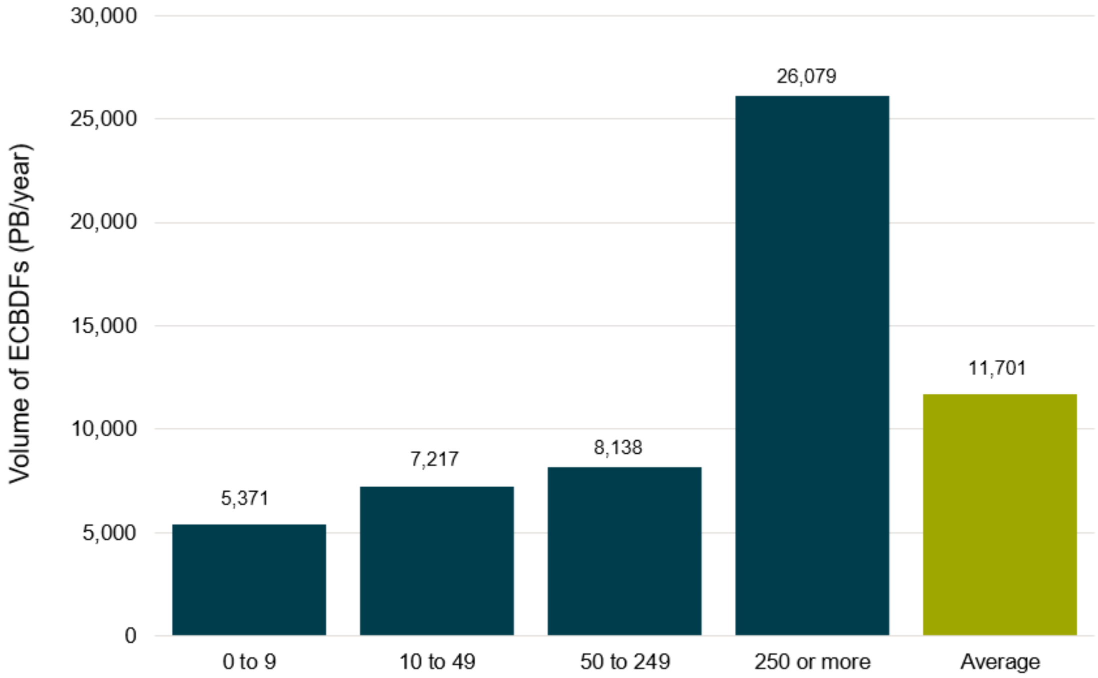


Table 3.5 ECBDF volumes in 2023 by enterprise size – EU, EFTA and UK (PB/year)

	0 to 9	10 to 49	50 to 249	250 or more
EU	3,828	5,133	5,833	19,645
EFTA	148	200	215	640
UK	1,394	1,883	2,089	5,793
Total Europe (EU + EFTA + UK)	**5,371**	**7,217**	**8,138**	**26,079**

d. Accounting for on-premises ECBDFs

One of the requirements of this research is to add an estimate of ECBDFs generated by the use of an on-premises private cloud **on top of the use of a public cloud only.**

An on-premises private cloud, also known as a “private cloud” or “internal cloud”,[51] refers to a cloud computing environment that is established and maintained within an organisation’s own physical data centre or infrastructure. In an on-premises private cloud, the organisation deploys and manages all the hardware, networking and software components necessary to create a cloud-like environment. This type of cloud offers the benefits of cloud computing, such as resource pooling, self-service provisioning and scalability, but it is located within the organisation’s own premises.

Eurostat statistics on cloud usage provide estimates of enterprises that buy public and private cloud services over the internet, but not on-premises private cloud (which is where the cloud

51 Microsoft Azure, definition of private cloud. Microsoft Azure, definition of private cloud.

computing environment is deployed and managed by a cloud user within the user's physical data centre, rather than deployed and managed by a third-party cloud provider).[52] As a result, we combined these statistics with other publicly available sources to estimate the proportion of enterprises that use this type of cloud services.

In summary, we find that cloud uptake including on-premises private cloud is likely to be approximately 15% higher than cloud uptake excluding on-premises private cloud. If we assume that the average ECBDFs generated by enterprises that use on-premises private cloud are the same as the average ECBDFs generated by enterprises that use other cloud service deployment modes (public, private hosted), we would conclude that the volume of ECBDFs estimated in all the previous subsections can be uplifted by approximately 15% to take account of the role of on-premises private cloud.

However, the assumption above is a strong assumption and obtaining detailed information on the prevalence and use of on-premises private cloud solutions is very challenging. Therefore, the 15% uplift above is an explorative indicative estimate and future research might want to explore this aspect in more detail and, in particular, might want to investigate potential differences between countries, sectors and years. In light of the explorative nature of this 15% uplift, none of the figures presented in the previous and following sections include on-premises cloud data flows. This addition is presented only in this subsection to provide an order of magnitude from which future studies might be able to progress research on this specific topic.

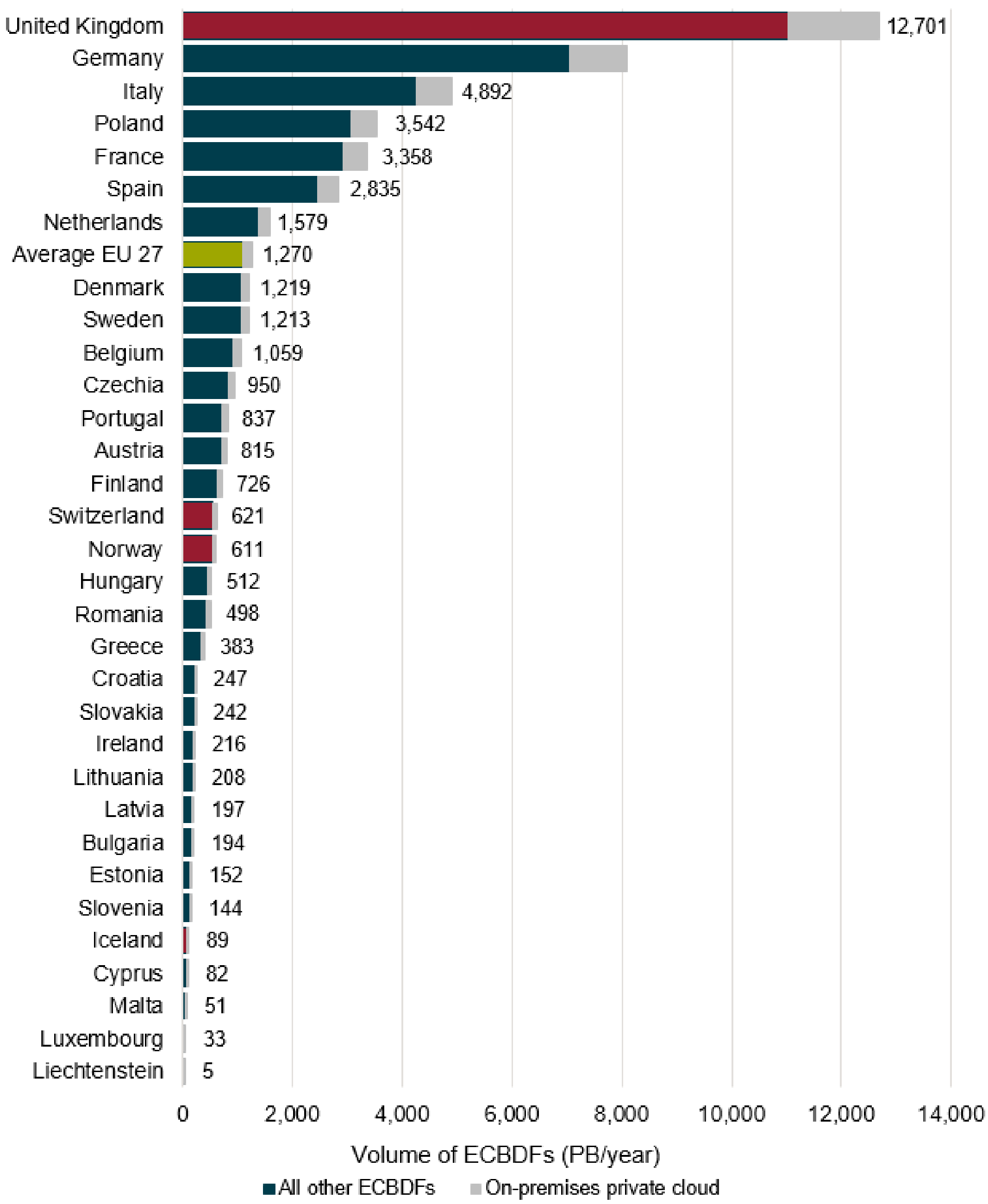
Figure 3.11 below shows our estimates of ECBDFs that include on-premises flows, broken down by country in 2023. As the 15% uplift is applied consistently to all countries and all years, the relative rankings of countries are the same as those presented, analysed and commented on with regard to Figure 3.1. In particular:

- The countries with the highest flows are the **UK, Germany, Italy, France and Poland**; and
- The countries with the lowest flows are **Liechtenstein, Luxembourg, Malta, Cyprus and Iceland.**

The numbers next to bars in the figure below refer to the sum of ECBDFs as calculated earlier in this chapter, and on-premises private flows are as calculated by our uplift.

[52] An on-premises private cloud, also known as a "private cloud" or "internal cloud" refers to a cloud computing environment that is established and maintained within an organisation's own physical data centre or infrastructure. In an on-premises private cloud, the organisation deploys and manages all the hardware, networking and software components necessary to create a cloud-like environment. This type of cloud offers the benefits of cloud computing, such as resource pooling, self-service provisioning and scalability, but it is located within the organisation's own premises. A hosted private cloud, also called a "managed private cloud" or "dedicated private cloud," is a cloud computing environment that is operated and managed by a third-party cloud service provider on behalf of an enterprise. In this model, the provider offers dedicated infrastructure and resources to a single organisation. The organisation's cloud environment is isolated from other customers, providing enhanced security and performance. The provider takes care of hardware provisioning, maintenance, security, updates and scaling, while the organisation can focus on deploying and managing its applications and services.

Figure 3.11 ECBDFs including on-premises cloud data flows in 2023 (PB/year)



Including our estimate for on-premises private cloud, we estimate that in 2023 enterprises that were operating in the EU and using cloud services generated approximately **34,300 PB/year of ECBDFs** (compared to 29,822 excluding on-premises private cloud). For EFTA (excluding the UK), this was **1,330 PB/year of ECBDFs** in 2023. For the UK, this was 12,700 PB/year of ECBDFs in 2023. For the total EU, EFTA and the UK, this was **48,300 PB/year of ECBDFs** in 2023**.**

As discussed in Chapter 1, we do not present estimates of ECBDFs broken down by type of cloud services because we do not have a data source that measures the data intensity/volume of different cloud services (e.g. emails versus data analytics).

e. Historic estimates of ECBDFs for 2016, 2018, 2020 and 2023

As mentioned above, this chapter has focused so far on estimates for the year 2023 (the latest year in which Eurostat collected data on cloud adoption statistics).

This section of Chapter 2 presents our estimated ECBDFs in 2016, 2018, 2020 and 2023, ordered by volume in ascending order, to provide a historical perspective over the period from the adoption (2016) and entry into force (2018) of the Free Flow of Non-Personal Data Regulation.

This Regulation aimed at promoting a free flow of data that stems from the cloud sector in Europe (i.e. intra-EU ECBDFs). Thus, looking **at patterns in ECBDFs prior to and after its adoption and implementation could provide useful information about the potential volume and economic impacts of the free flow of data on the European internal market.**

In this context, it is important to note that many of the assumptions of this study made to estimate the volume of ECBDFs before 2021 are assumed to remain constant in previous years (e.g. proportion of enterprise internet traffic flowing to cloud facilities, market shares of main cloud providers, etc.). This element should be taken into account when conducting future potential ex-post evaluations of this Regulation together with the following aspects:

- **Causality and attribution:** establishing causality is crucial in understanding whether the observed outcomes can be attributed to the policy intervention or other external factors. In a context like this, where randomised control trials (RCTs) or quasi-experimental methods cannot be implemented, it is essential to consider a series of counterfactual scenarios to determine what would have happened in the absence of the policy.
- **Data quality and availability:** it is important to ensure that the data used for evaluation is reliable, comprehensive and relevant. In this context, it might be helpful to complement this quantitative data with qualitative infromation.

As shown in the charts below, the total volume of EU ECBDFs is estimated to have increased by a factor of **20 between 2016 and 2023**, mainly due to a rapid increase in enterprise internet traffic and to a steady increase in enterprise cloud usage. The biggest increase was experienced in Poland, Portugal, Lithuania, Germany and Estonia, while the smallest increase was found in Bulgaria, Finland, Denmark, Czechia and Ireland.

Figure 3.12 ECBDFs generated by each European country in 2016, 2018, 2020, and 2023

f. Forecast volume of ECBDFs for 2024, 2025, 2030 and 2035

This section presents the results of our ECBDF forecasting. By 2030, in the EU, the total volume of ECBDFs is estimated to increase by **around 20 times** (compared to 2023) to approximately 600,000 PB/year. Forecasts are then expected to reach 5.6m PB/year by 2035, **an increase of approximately 186 times** from 2023.

Figure 3.13 below shows the same estimates for the totality of the countries analysed in this report.

Figure 3.13 Aggregate volume of ECBDFs over time (EU + EFTA + UK)[53]

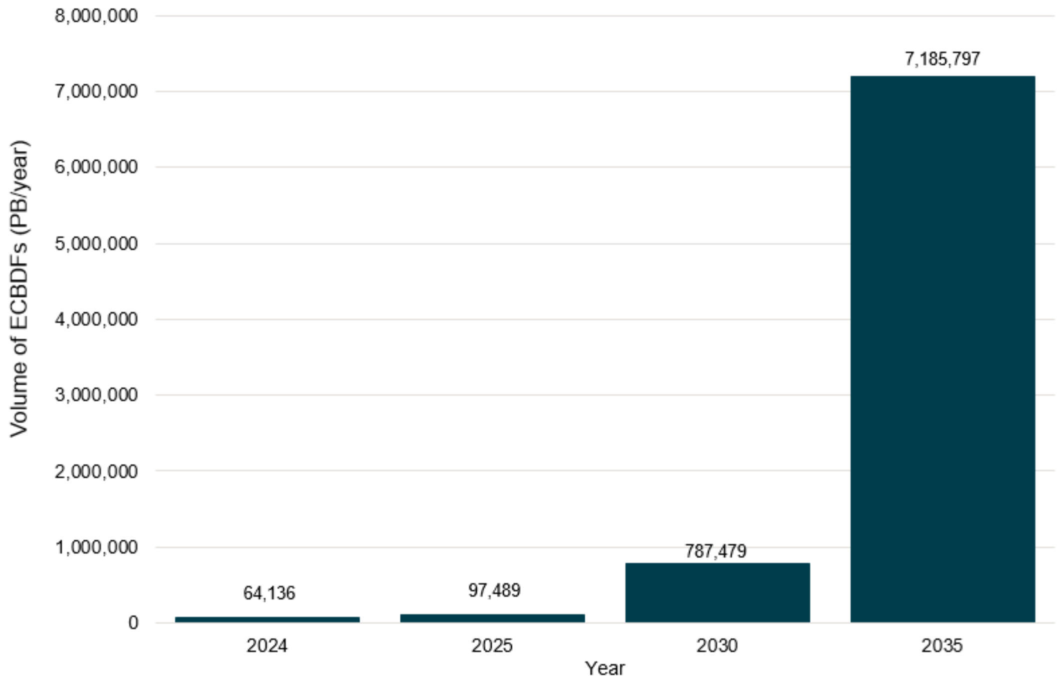


Table 3.6 Forecast ECBDF volumes in 2024, 2025, 2030 and 2045 (PB/year)

	2024	2025	2030	2035
EU	45,893	70,300	588,926	5,559,233
EFTA	1,725	2,585	20,311	185,946
UK	16,517	24,604	178,243	1,440,618
Total Europe (EU + EFTA + UK)	**64,136**	**97,489**	**787,479**	**7,185,797**

As shown in Figure 3.14 below, the countries that are expected to see the greatest relative increase in ECBDFs volumes between 2023 and 2035 are **Austria, Finland and the Baltics**, where ECBDFs are estimated to grow by a factor of more than 300 from 2023 and 2035 (and by around 30 times from 2023 to 2030). This ranking is mainly driven by different future growth rates of internet traffic and of enterprise usage of cloud services. These countries have a relatively high proportion of internet traffic being mobile internet traffic (30%-66%), which we forecast to grow at a higher annual growth rate (56%) compared to fixed internet traffic (29%), based on historic growth rates.[54]

The countries with the lowest estimated relative increase are in 2023, **the UK, Germany, Cyprus, Liechtenstein and the Netherlands**, where ECBDFs are estimated to grow by a factor of around 130 (and by around 16 times between 2023 and 2030). These countries all have relatively high percentages of internet traffic that is fixed internet traffic (around 90%), meaning their growth is relatively lower.

53 Please note that 25% of the total ECBDFs that flow to main cloud data centres are constantly assumed to flow to other regions (e.g. around 1.8m PB are assumed to flow to regions outside Europe).

54 See the methodological note for more explanation of sources and assumptions for internet traffic.

Figure 3.14 Volume of ECBDFs per country forecast to 2024, 2025, 2030 and 2035

In general, these large increases in estimated ECBDFs have two key drivers.

Firstly, by far the main driver of this increase is our assumption of a stable growth rate from 2023 to 2036 of both mobile (56% per annum) and fixed (29% per annum) internet traffic from 2022 (the latest year for which actual data on internet traffic is available) until the end of the forecast period. We derive these growth rates from the average growth rates prior to 2022, but we exclude 2020-2021 due to Covid causing anomalously high growth rates in these years as individuals spent more time indoors during lockdown. The volume of internet traffic therefore compounds over time as these same growth rates are applied to larger and larger volumes.

Secondly, we assume, inferring from the historical data, that there will continue to be a steady increase in the number of enterprises that use cloud services over time (the exact rate of increase varies by country and sector).

This increase is therefore based on the assumption that the growth in internet traffic and cloud usage observed in the years before the pandemic will continue for the foreseeable future. While this is an assumption that might be disproved by actual trends, it is in line with other studies and forecasts published on internet traffic growth.[55]

In fact, according to these sources, the widespread adoption of emerging technologies, such as the Internet of Things (IoT) and 5G connectivity, is widely expected to revolutionise the digital landscape. These advances will lead to an increase in connected devices, ranging from smart home appliances to industrial machinery, contributing significantly to the overall volume of data transmitted over the internet (and also to cloud facilities). This does not mean that IoT devices are expected to increase by a factor of 100 in the period under analysis; it means that the data flows generated by these devices are expected to do so. For example, one would not expect the number of passenger vehicles to increase dramatically over the next 15 years. However, as more and more of these vehicles will be connected to internet infrastructure and will require data flows to operate, they are expected to generate significantly more data flows over time. In addition, as more industries embrace digital transformation, the demand for seamless and high-speed internet connectivity will propel the surge in internet traffic.

As discussed in more detail in Section 1.c of the methodological note, we forecast future numbers of employees and the percentage share of enterprises that buy cloud services (both by country, firm size and sector) using the historical compound average growth rate (CAGR) observed in the recent past. More specifically:

- For the percentage share of enterprises that buy cloud services, we used an S-curve approach: in other words, we apply a lower growth rate in some future years to prevent the percentage share of businesses from rising too high. Specifically, we assume the maximum uptake rate to be 95% and apply a log function to reduce growth in cloud uptake if it begins to approach 95% during the forecasting period.
- This approach is sensible given that most technology adoption follows an S-shape, with a relatively slower increase in technology adoption early (at the beginning of the S-curve) and late (at the end) in the adoption cycle. An example of this S-curve is shown in Figure 3.15 below.
- As there is evidence that cloud uptake accelerated significantly during the pandemic but that its growth rate slowed down afterwards, forecasting future cloud uptake using data observed during the pandemic (2020 and 2021) might lead to biased estimates. Similarly, employment across Europe declined during 2020 from 2019 due to the pandemic-induced recession. As a result, we drop 2020-2021 for the CAGR used to forecast both the employment and cloud uptake data in the future, and use only the years 2016-2019 instead.

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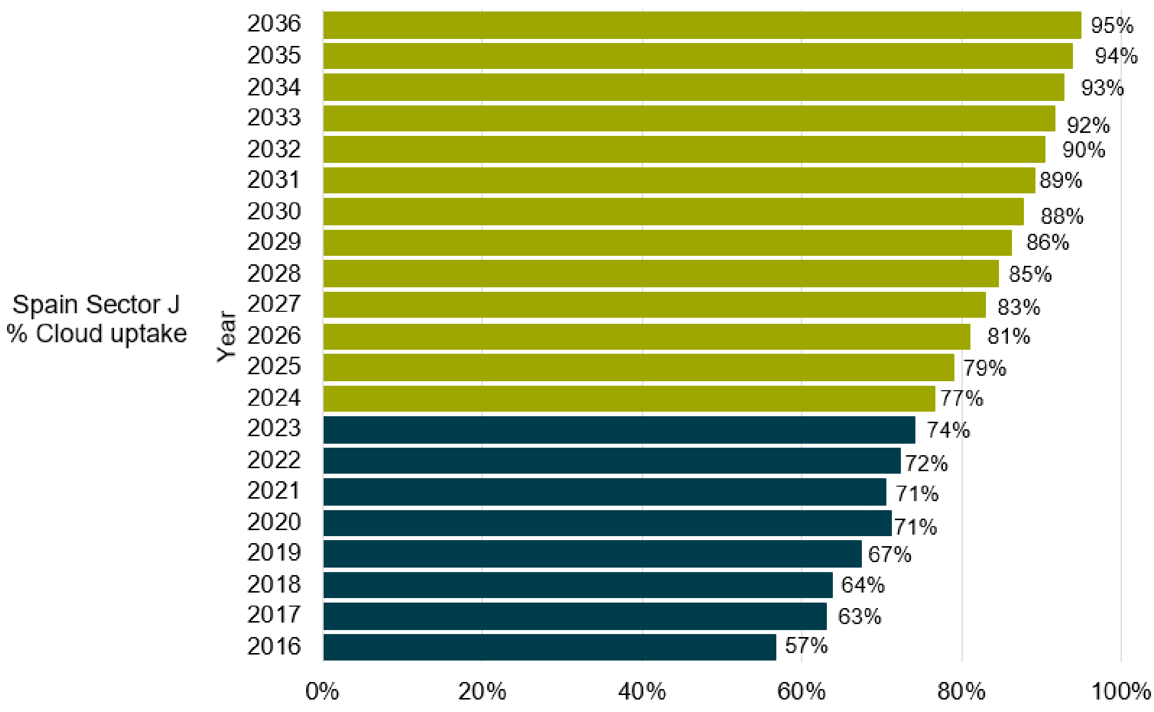
55 See Figure 14 of the Ofcom discussion paper on mobile traffic, and Telegeography's State of the Network Report

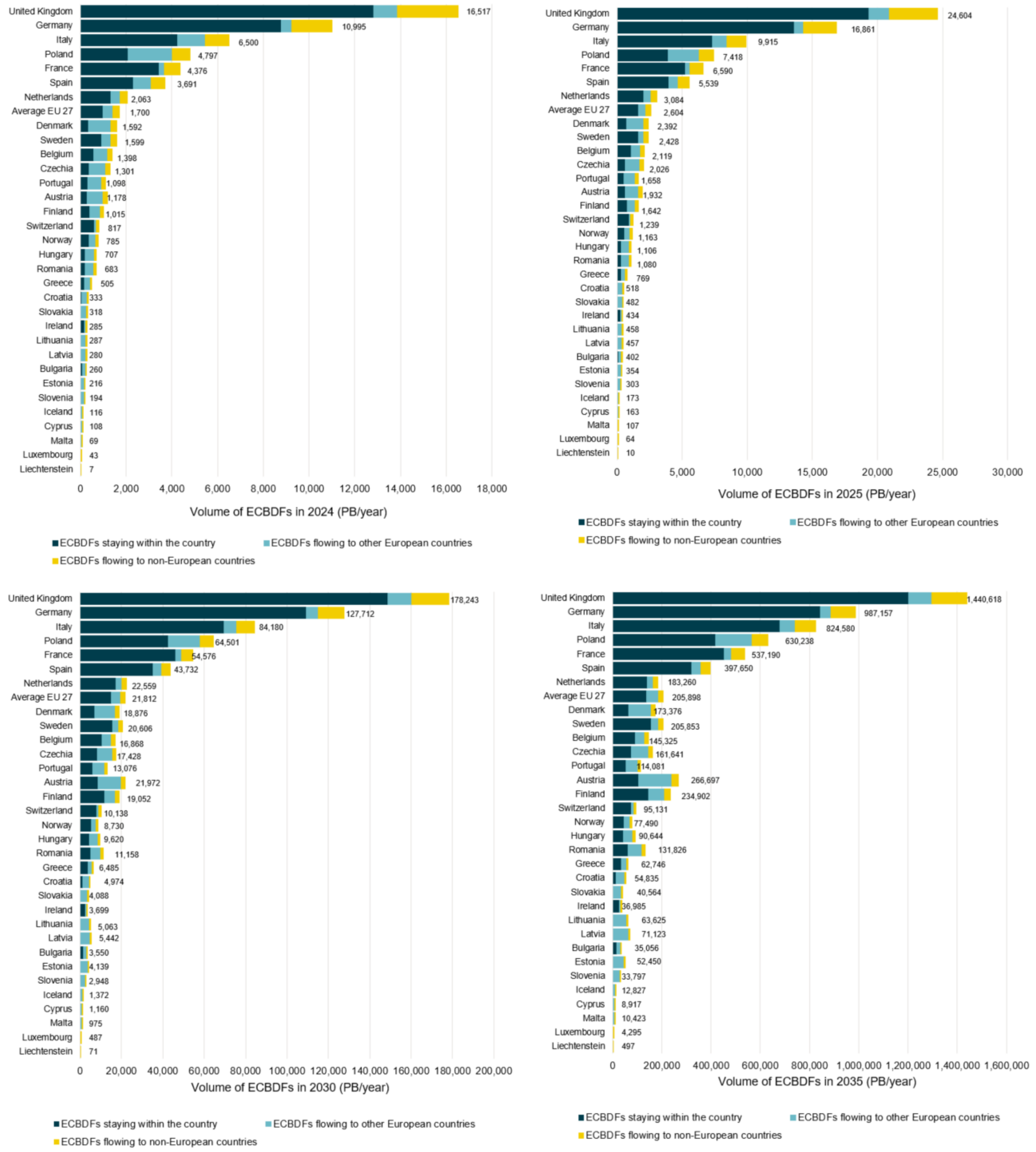
Figure 3.15 Example of S-shaped cloud adoption (Spain, Sector J)



In terms of future forecasts, the proportion of ECBDFs which stay within the country that generated them or within Europe is expected to increase over time. This is due to the assumption that an increasing proportion of cloud traffic will be directed to edge centres instead of main cloud centres, which results in more ECBDFs staying in Europe. Also the assumption that more data centres will be built in more countries over time contributes to this increasing relevance of within-country ECBDFs over time (in line with the information gathered from publicly available websites of major cloud providers[56]). Therefore, we estimate that both within-country and extra-country ECBDFs will increase over time, but within-country ECBDFs will increase at a faster rate.

56 Links are provided in the Annexes to the methodological note accompanying this report.

Figure 3.16 ECBDFs generated by each European country and destination forecast to 2024, 2025, 2030, and 2035[57]



In Figure 3.16 above, note the increasing scale on the axes as the volume increases. There is also a slight reordering of countries in terms of the total volume of ECBDFs over time due to differing cloud uptake growth rates, workforce growth and new data centres (both edge and cloud ones) being built, which results in new inflows across European countries.

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57 All ordered using 2023 totals.

To see the effect of new main and edge data centres being built more closely, we can observe the net inflows over time, both including and excluding flows that remain in the country, as presented in the tables below.

In Table 3.7 below, there are three countries that flip from negative to positive inflows across this time period – **Greece, Italy and Spain**. All these countries have a data centre from one of the two largest providers planned or under construction during the forecasting period, which is what drives the increased inflows. By the end of the period, Italy is expected to receive the second most inflows in Europe after Germany, followed by Sweden, France and Switzerland.

Table 3.7 Net inflows of ECBDFs in 2023, and forecast to 2024, 2025, 2030, and 2035

	2023	2024	2025	2030	2035
Germany	3,315	4,402	5,508	35,006	353,769
France	1,564	1,779	1,660	8,665	75,481
Switzerland	859	988	916	5,396	59,781
Norway	342	310	81	5	2,218
Netherlands	163	274	447	6,514	59,136
Sweden	116	300	670	7,477	90,763
Ireland	26	40	63	522	2,934
Liechtenstein	- 4	- 6	- 9	- 64	- 447
Luxembourg	- 24	- 36	- 54	- 438	- 3,865
Malta	- 37	- 58	- 91	- 878	- 9,380
Cyprus	- 59	- 91	- 138	- 1,044	- 8,025
Iceland	- 64	- 97	- 147	- 1,235	- 11,545
Bulgaria	- 97	- 144	- 214	- 1,508	- 14,892
Greece	- 98	- 78	2	1,090	10,463
Slovenia	- 104	- 163	- 257	- 2,654	- 30,418
Estonia	- 109	- 182	- 301	- 3,725	- 47,205
Italy	- 117	287	1,256	13,367	134,268
Latvia	- 142	- 235	- 388	- 4,898	- 64,011
Croatia	- 144	- 219	- 335	- 2,962	- 32,568
Lithuania	- 150	- 241	- 389	- 4,557	- 57,263
Slovakia	- 175	- 267	- 410	- 3,679	- 36,507
Hungary	- 205	- 300	- 430	- 1,733	- 12,095
Finland	- 221	- 261	- 244	- 1,492	- 18,560
Romania	- 250	- 379	- 576	- 4,740	- 56,000
United Kingdom	- 308	- 514	- 851	- 6,918	- 50,559
Portugal	- 420	- 609	- 884	- 5,555	- 48,461
Spain	- 435	- 330	65	1,730	15,161
Austria	- 441	- 578	- 665	- 8,024	- 104,606
Czechia	- 448	- 671	- 991	- 6,077	- 53,802
Belgium	- 467	- 602	- 728	- 4,406	- 37,934
Denmark	- 712	- 959	- 1,246	- 9,269	- 85,055
Poland	- 1,155	- 1,359	- 1,318	- 3,919	- 20,777

Table 3.8 Net ECBDFs processed in the country in 2023, and forecast to 2024, 2025, 2030, and 2035

	2023	2024	2025	2030	2035
Germany	8,876	13,177	19,125	144,214	1,197,899
United Kingdom	8,156	12,306	18,487	141,944	1,152,591
France	3,832	5,219	6,903	54,698	528,588
Italy	2,337	4,532	8,595	82,831	814,701
Switzerland	1,251	1,589	1,837	13,382	134,719
Netherlands	1,009	1,591	2,484	23,920	200,533
Spain	921	1,994	4,057	37,051	336,333
Sweden	642	1,222	2,289	23,243	248,264
Norway	586	688	665	5,332	49,497
Ireland	146	226	350	3,167	29,383
Liechtenstein	- 4	- 6	- 9	- 64	- 447
Greece	- 11	98	346	4,884	47,182
Luxembourg	- 24	- 36	- 54	- 438	- 3,865
Finland	- 28	137	556	10,278	126,557
Malta	- 37	- 58	- 91	- 878	- 9,380
Bulgaria	- 54	- 70	- 87	179	1,767
Cyprus	- 59	- 91	- 138	- 1,044	- 8,025
Iceland	- 64	- 97	- 147	- 1,235	- 11,545
Poland	- 86	719	2,611	38,823	396,858
Hungary	- 92	- 99	- 80	2,838	30,979
Slovenia	- 104	- 163	- 257	- 2,654	- 30,418
Estonia	- 109	- 182	- 301	- 3,725	- 47,205
Croatia	- 113	- 166	- 244	- 1,643	- 18,026
Romania	- 140	- 184	- 234	562	6,644
Latvia	- 142	- 235	- 388	- 4,898	- 64,011
Lithuania	- 150	- 241	- 389	- 4,557	- 57,263
Belgium	- 173	- 35	335	6,268	54,018
Slovakia	- 175	- 267	- 410	- 3,679	- 36,507
Portugal	- 235	- 296	- 359	659	5,750
Czechia	- 238	- 300	- 350	2,205	23,010
Austria	- 327	- 301	- 46	658	776
Denmark	- 556	- 607	- 515	- 2,093	- 19,142

We also forecast the volume of ECBDFs that flow from Europe to other regions, which is expected to increase from 7,300 PB/year for the EU and 2,900 PB/year for EFTA and the UK in 2023 to 556,000 PB and 163,000 PB respectively in 2035. The relative importance of different regions and countries is assumed to remain the same over the period under analysis. This is due to data limitations (i.e. information on future submarine cables and intercontinental infrastructure is not publicly available), but it is consistent with what we observe within Europe (i.e. the relative position of most countries is relatively stable). In particular, the "top" destinations of extra-European ECBDFs within each region are:

- The USA and Canada in North America
- Israel and the UAE in the Middle East
- South Africa in Africa
- China and Japan in Asia

Table 3.9 Breakdown of ECBDFs that flowed from Europe to other regions in 2023, and forecast to 2024, 2025 and 2035 (PB/year)

	2024		2025		2035	
	EU	**EFTA+UK**	**EU**	**EFTA+UK**	**EU**	**EFTA+UK**
USA	799	318	1,147	444	60,491	17,699
Canada	799	318	1,147	444	60,491	17,699
Total North America	**1,598**	**635**	**2,295**	**888**	**120,982**	**35,398**
Turkey	84	33	120	47	6,339	1,855
Israel	768	305	1,103	427	58,167	17,019
UAE	676	269	970	375	51,152	14,966
Barhain	361	143	518	200	27,323	7,994
Qatar	365	145	525	203	27,666	8,095
Saudi Arabia	441	175	633	245	33,380	9,767
Total Middle East	**2,695**	**1,071**	**3,870**	**1,497**	**204,026**	**59,695**
Egypt	13	5	18	7	966	283
South Africa	1,189	473	1,708	660	90,031	26,342
Total Africa	**1,202**	**478**	**1,726**	**668**	**90,997**	**26,625**
China	319	127	458	177	24,128	7,060
Japan	351	139	504	195	26,548	7,768
India	303	120	435	168	22,930	6,709
Indonesia	153	61	220	85	11,591	3,391
Taiwan	29	12	42	16	2,203	645
South Korea	303	120	435	168	22,930	6,709
Malaysia	4	2	6	2	301	88
Thailand	12	5	18	7	945	277
Singapore	374	149	538	208	28,344	8,293
Total Asia	**1,848**	**735**	**2,654**	**1,026**	**139,919**	**40,939**
Total	**7,343**	**2,919**	**10,545**	**4,078**	**555,923**	**162,656**

In the final two tables of this chapter, we present the forecasting for extra-ECBDFs, and forecast breakdowns by NACE sector and size band from 2024 to 2035.

In terms of future forecasts, future ECBDFs are estimated to grow consistently across all firm sizes and all sectors. This is mainly because of the exponential growth expected in enterprise internet traffic across all countries and sectors, and also because of expected increases in cloud uptake. ECBDFs from the water, construction, transportation and accommodation sectors are expected to grow somewhat faster than other sectors (by a factor of around 220 compared to 190 for EU ECBDFS as a whole), but the distribution of ECBDFs by sector is expected to remain very similar between 2023 and 2035 (for example, the transportation sector accounts for 4.5% of EU ECBDFs in 2023, and it is expected to account for 5.4% in 2035).

Table 3.10 EU ECBDFs broken down by NACE sector in 2023, and forecast to 2024, 2025, 2030 and 2035 (PB/year)

	2023	2024	2025	2030	2035
Manufacturing (C)	4,840	7,558	11,697	100,003	944,594
Electricity, gas, steam and air conditioning supply (D) ….	256	392	597	4,894	45,361
Water supply; sewerage, waste management and remediation activities	212	335	524	4,723	46,880
Construction	1,700	2,661	4,145	37,490	376,583
Wholesale and retail trade; repair of motor vehicles and motorcycles	4,125	6,379	9,807	82,994	788,364
Transportation and storage	1,330	2,088	3,260	29,634	298,080
Accommodation and food service activities	1,005	1,608	2,542	23,574	237,035
Information and communication	1,986	2,888	4,218	30,049	256,748
Financial and insurance activities	1,275	1,886	2,796	20,964	184,858
Real estate activities	344	517	776	6,136	56,426
Professional, scientific and technical activities	2,457	3,640	5,405	41,034	366,790
Administrative and support service activities	1,244	1,924	2,958	24,961	235,447
Public administration and defence; compulsory social security	2,103	3,261	5,022	42,463	399,913
Education	2,200	3,407	5,246	44,703	426,631
Human health and social work activities	3,400	5,264	8,095	68,024	636,504
Arts, entertainment and recreation	496	768	1,182	10,182	98,802
Other service activities	848	1,316	2,028	17,095	160,218
Total EU	**29,822**	**45,893**	**70,300**	**588,926**	**5,559,233**

Note: C=Manufacturing; D=Electricity, Gas, Steam and Air Conditioning Supply; E=Water Supply; Sewerage, Waste Management and Remediation Activities; F=Construction; G=Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H=Transportation and Storage; I=Accommodation and Food Service Activities; J=Information and Communication; K=Financial and Insurance Activities; L=Real Estate Activities; M=Professional, Scientific and Technical Activities; N=Administrative and Support Service Activities; O=Public Administration and Defence; Compulsory Social Security; P=Education; Q=Human Health and Social Work Activities; R=Arts, Entertainment and Recreation; S=Other Service Activities. Sectors A (Agriculture, Forestry and Fishing) and B (Mining and Quarrying) are not included in the analysis as there is no data on cloud uptake available on Eurostat and none of the other sectors is sufficiently comparable to generate a proxy.

Please note that, as explained in Section 2 of the report, the estimates presented below are generated using cloud uptake by country and size band as one of the key inputs in our calculations, rather than cloud uptake by country-sector as for all other estimates of ECBDF volumes. As a result, there is a small difference between the total ECBDF volume across all size bands shown below and the total ECBDF volume reported earlier in this section.

Table 3.11 ECBDFs broken down by enterprise size (number of employees size band) in 2023, and forecast to 2024, 2025, 2030 and 2035

Size (number of employees)	2023	2024	2025	2030	2035
0 to 9	3,828	6,594	11,017	120,379	1,325,827
10 to 49	5,133	8,044	12,488	108,324	1,037,034
50 to 249	5,833	8,725	13,055	101,107	909,765
250 or more	19,645	28,522	41,605	294,575	2,502,788
Total Europe (EU + EFTA + UK)	**34,440**	**51,885**	**78,164**	**624,384**	**5,775,414**

Lastly, with regard to the split between ECBDFs that flow to main data centres and ECBDFs that flow to edge facilities, Figure 3.17 below shows the assumptions made to forecast this split over time between 2024 and 2035.[58] As explained in more detail in the methodology note, these assumptions are based on the following considerations:

- The European Commission's European Data Strategy aimed for edge facilities to account for 80% of data storage by 2025.[59] In addition, this trajectory was supported by independent industry forecasts.[60] These expectations were reflected in the Ipsos/Tech4i2 study, which assumed that the total share of enterprise data hosted in main cloud facilities would decrease from 80% in 2020 to 4% in 2030, while the share of data storage in edge cloud facilities would increase from 20% in 2020 to 96% in 2030.[61]
- However, we understand that the growth of edge data storage is occurring more slowly than initially anticipated by policymakers. According to the recently published[62] EC 2023 Report on the State of the Digital Decade,[63] "*the development of edge nodes is at a very early stage […] very far from the objective of 10,000 secure, sustainable edge nodes by 2030".* As a result, as shown in Figure 3.17, in order to reflect this slower growth, we have assumed that 60% of total data storage will be in edge facilities only

58 While this report includes forecasts up to 2035, the online monitoring tool also includes forecast ECBDF volumes in 2036.

59 Europe's Digital Decade: digital targets for 2030 (europa.eu). .

60 For example, see Gartner (2018), Llorente (2021) and Huawei (2021). These sources have been used by Ipsos/Tech4i2 to refine forecasts of edge/cloud ratios between 2020 and 2023

61 Ipsos/Tech4i2 estimates that the share of data that flows to edge cloud facilities would reach 80% in 2026 or 2027, assuming an S-shaped curve approach for edge share to avoid reaching a 100% share in 2029 and 2030.

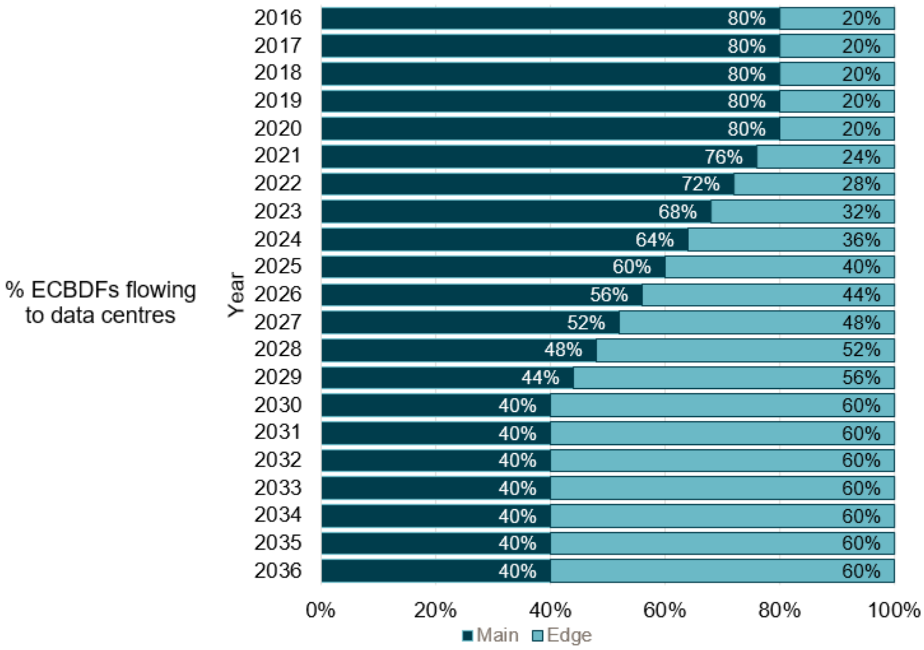
62 27 September 2023.

63 https://digital-strategy.ec.europa.eu/en/library/2023-report-state-digital-decade

as of 2035 rather than in 2025. Using this assumption, we create a linear trend from 20% (in 2020) to 60% (in 2035) of total data storage in edge facilities.[64] This assumption is used consistently for intra-European and extra-European flows as well as for the ECBDFs generated in every European country under analysis (EU, EFTA and UK).

- When such evidence becomes available, this research could be updated using the figures that will be produced by the *2030 Digital Decade Policy Programme* (DDPP) to achieve both the enterprise cloud uptake and edge node deployment targets of the 2030 Europe's digital transformation, which formally started in January 2023.

Figure 3.17 Percentage of enterprise cloud traffic that flows to edge data centres in Europe



[64] We also reviewed the recent study produced by the EU Edge Observatory, but it does not include sufficient information to refine this quantitative assumption further.

4. Main results and conclusions on the economic value of ECBDFs

a. Application of our framework to estimate the value of ECBDFs

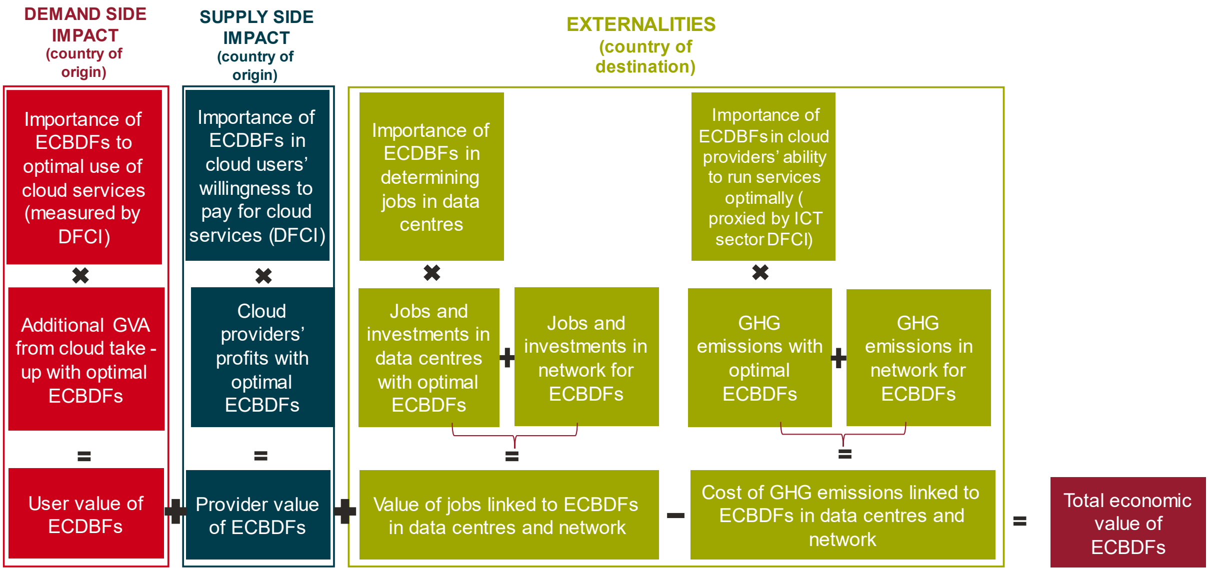
As described in Chapter 1, we estimate the economic value of ECBDFs from the perspective of three different economic entities:

- The enterprises that use cloud services (**demand-side** or **user perspective**);
- The providers of cloud services (**supply-side** or **provider perspective**); and
- The wider economy/society (**externalities**).

In this chapter, we describe the results obtained from the application of our methodology to estimate demand-side value, supply-side value and externalities, and then report the overall value of ECBDFs for the EU as a whole, and for each EU Member State, EFTA country and for the UK.

Figure 4.1 below summarises our approach and the results included in this chapter at a high level. Further detail on our conceptual framework and on the technical details of the analysis is included in our methodological note [link].

Figure 4.1 Graphical summary of conceptual framework to measure the economic value of ECBDFs

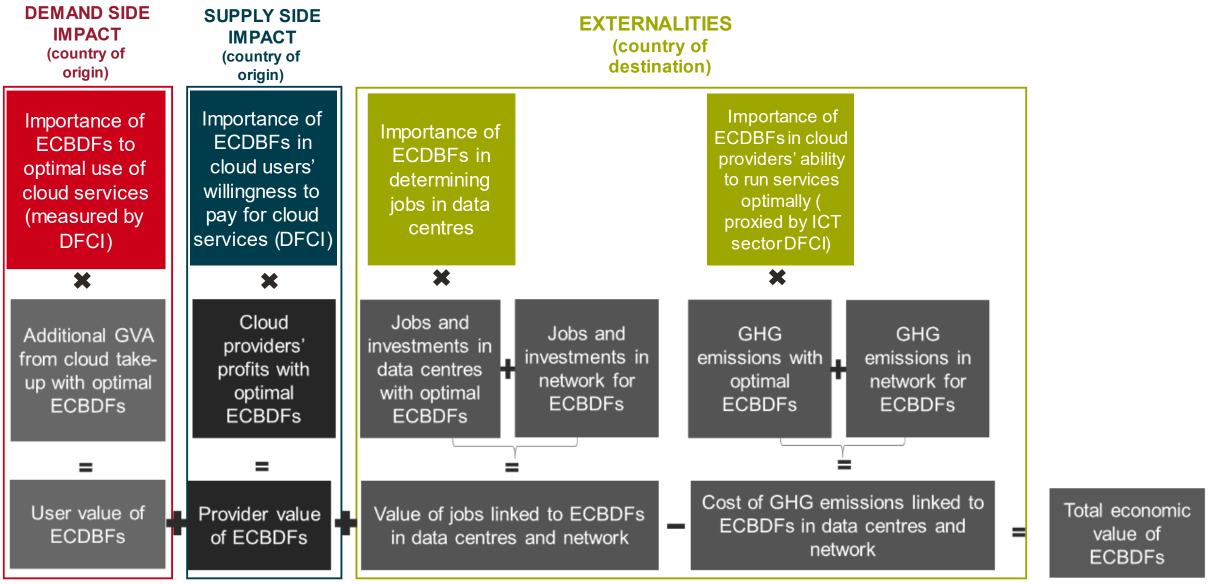


As shown in the figure, the Data Flows Criticality Index (DFCI) is a key component in the calculation of demand-side value, supply-side value and externalities: **it is through this index that we separate the specific value of ECBDFs from the value of cloud services to enterprises that use cloud services, the profits of cloud providers and the broader externalities generated in cloud data centres.**

Therefore, in this chapter we first describe the results of our estimation of the DFCI, before presenting our estimates of the demand-side value (Section 3.c); supply-side value (Section 3.d); externalities (Section 3.e); and total value of ECBDFs (Section 3.f).

When relevant, some of the charts that follow in this chapter are coloured according to whether the value pertains to an EU Member State (blue), an EFTA country or the UK (red), or the EU average (grey).[65]

b. Importance of ECBDFs to enterprises that use cloud services (estimated/measured by the DFCI)



Note: the diagram presented in Figure 4.1 will be shown at the beginning of each subsection to guide the reader by highlighting the segment of the framework that is described in each subsection. The coloured boxes are the ones discussed in the following text. The grey boxes are other parts of the framework discussed in other subsections. Please note that these "guiding" diagrams are not numbered as all other figures.

The DFCI is a composite index that aims to measure the extent to which ECBDFs are critical for the realisation of the value of cloud-based services. As shown in the box overleaf, the DFCI is multiplied by:

- Our estimate of the value of cloud services to enterprises using those services (measured as the additional GVA produced by these enterprises with unconstrained ECBDFs, hereinafter "user value of cloud services"), to estimate the demand-side value of ECBDFs;
- Our estimate of the profits of cloud providers from serving the enterprises that generate ECBDFs, to estimate the supply-side value of ECBDFs**;** and
- Our estimate of the value of jobs and GHG emissions required for cloud data centres to receive, process and store the data included in the ECBDFs, to estimate the externalities from ECBDFs.

As described in Chapter 1, we estimate the DFCI for each country-sector using data from Eurostat on eight indicators which proxy three drivers that increase the importance of ECBDFs for an enterprise's ability to derive value from its use of cloud services. The three drivers and their underlying indicators are listed in Table 4.1 below; the following box provides a practical example of the calculation and application of the DFCI. Further detail on the DFCI and its composition is provided in Section 3 of the methodological note accompanying this report.

65 The EU value is intentionally coded as grey in this chapter, compared to green in chapter 2. This and other small formatting differences between the chapter serve the purpose of making it easier to distinguish the volume and value figures.

Table 4.1 Components of the DFCI

Driver	What this driver measures	Indicators used to measure this driver for each country-sector	Rationale for indicator selection (examples)
Optimal use of cloud-based capabilities	The extent to which the enterprise efficiently uses cloud-based capabilities that rely upon a minimum volume of ECBDFs	Indicator C1: % of enterprises in the country-sector that use big data analysis Indicator C2: % of enterprises in the country-sector that use AI Indicator C3: % of enterprises in the country-sector that use IoT technologies	For enterprises that use capabilities such as big data analysis, AI, IoT, constraints on data flows would mean they would use lower volume, variety or velocity of data. This would limit the usefulness of those capabilities.
Access to customers	The extent to which the enterprise requires ECBDFs to be able to provide goods or services to customers	Indicator A1: % of enterprises in the country-sector with e-commerce sales Indicator A2: % of enterprises in the country-sector that export	Enterprises with high e-commerce sales and exporting enterprises are more likely than other enterprises to be located remotely from their customers. Consider a geographical restriction to ECBDFs where data cannot flow across borders. In this case, enterprises that are reliant on e-commerce sales will not be able to sell to customers located remotely in other countries. Enterprises that export and use cloud services to monitor the movement of their inputs and their products around the world would also be constrained.
Security	The extent to which the enterprise requires ECBDFs to design or benefit from resilient cloud architectures and redundant data storage to run its operations	Indicator S1: % of enterprises in the country-sector that use data back-up architecture to a separate location Indicator S2: % of enterprises in the country-sector that have insurance services against ICT security incidents Indicator S3: % of enterprises in the country-sector that use at least three ICT security measures	These indicators measure the extent to which cloud-using enterprises in a sector require geographically unconstrained ECBDFs for data back-up (S1); the extent to which their cloud-based ICT security architecture may be challenged (S2); and the extent to which they have put in place specific ICT security measures that may rely on ECBDFs (S3).

A practical example of the calculation and application of the DFCI

Calculation of the DFCI

- We generate DFCI values for 17 sectors in each of 32 countries (EU Member States, EFTA countries and the UK), for a total of 544 values. Each country-sector value (e.g. the value of the ECBDF for the manufacturing sector in Spain) is calculated through the following steps.
- We first normalise the value of each of the eight component indicators so that they range between 0% (for the country-sector with the lowest value of that indicator across all 544 country-sectors) and 100% (for the country-sector with the highest value of that indicator across all 544 country-sectors).
- Once normalised values of the indicators C1, C2, C3, A1, A2, S1, S2, S3 have been calculated, these are averaged up to driver level. For example, the "optimal use of cloud capabilities" driver C is calculated for each country *c* and sector *s* as:
- $C_{c,s} = \frac{C1_{c,s} + C2_{c,s} + C3_{c,s}}{3}$
- The driver values are then averaged up into an **overall DFCI value for the country-sector**:

$$DFCI_{c,s} = \frac{1}{3}C_{c,s} + \frac{1}{3}A_{c,s} + \frac{1}{3}S_{c,s}$$

A worked example of the calculation of the DFCI is provided in the accompanying methodological note [link].

Application of the DFCI

- To calculate the **value of ECBDFs to enterprise users in a given country-sector**, we multiply the DFCI value by our estimate of the value of cloud services to those users (VU):

$$VU(ECBDF_{c,s}) = VU_{c,s} * DFCI_{c,s}$$

- To **calculate the value of ECBDFs that originate from country c to cloud providers (VP)**, as described in Chapter 1, we use the average country-level DFCI, multiplied by our estimate of cloud provider profits P that originate from that country:

$$VP(ECBDF_c) = P_c * DFCI_c$$

- To calculate **the value of externalities** from the activities of cloud data centres in country *c* linked to ECBDFs, we use the DFCI value for the ICT sector in the country of destination of the data flows (*c*), multiplied by the value of jobs in cloud data centres and the GHG emissions generated by the data centres:

$$VE(ECBDF_c) = E_d * DFCI_{d,ICT}$$

We calculate the values of this index for each sector (NACE rev.2) within each country in the EU, EFTA and UK, and we also compute different values for basic cloud services versus intermediate and sophisticated services based on the DFCI.

Figure 4.2 below shows the average values of the DFCI for each country in our sample (see footnote for how we calculate each country-level DFCI figure from its sector-level DFCI figures).[66] The country DFCI ranges from 14% (Romania) to 71% (Denmark).

This means that, according to our methodology, in Romania, ECBDFs account for around 14% of the value to Romanian enterprises that use cloud-based services (demand-side value) and for 14% of the profits generated by cloud providers when serving Romanian enterprises with cloud services (supply-side value).

Denmark, Finland, Ireland and Sweden have noticeably higher DFCI values than all other EU countries, including Belgium and the Netherlands, which have the fifth and sixth value in the EU respectively. The top four countries score highly on all indicators that make up the DFCI, meaning that ECBDFs are highly critical for enterprises in those countries to make optimal use of cloud-based capabilities, access customers and benefit from/build secure cloud architectures. Within this group, the criticality of ECBDFs for cloud-based capabilities is particularly high for Finland, and the criticality for access to customers is particularly high in Ireland.

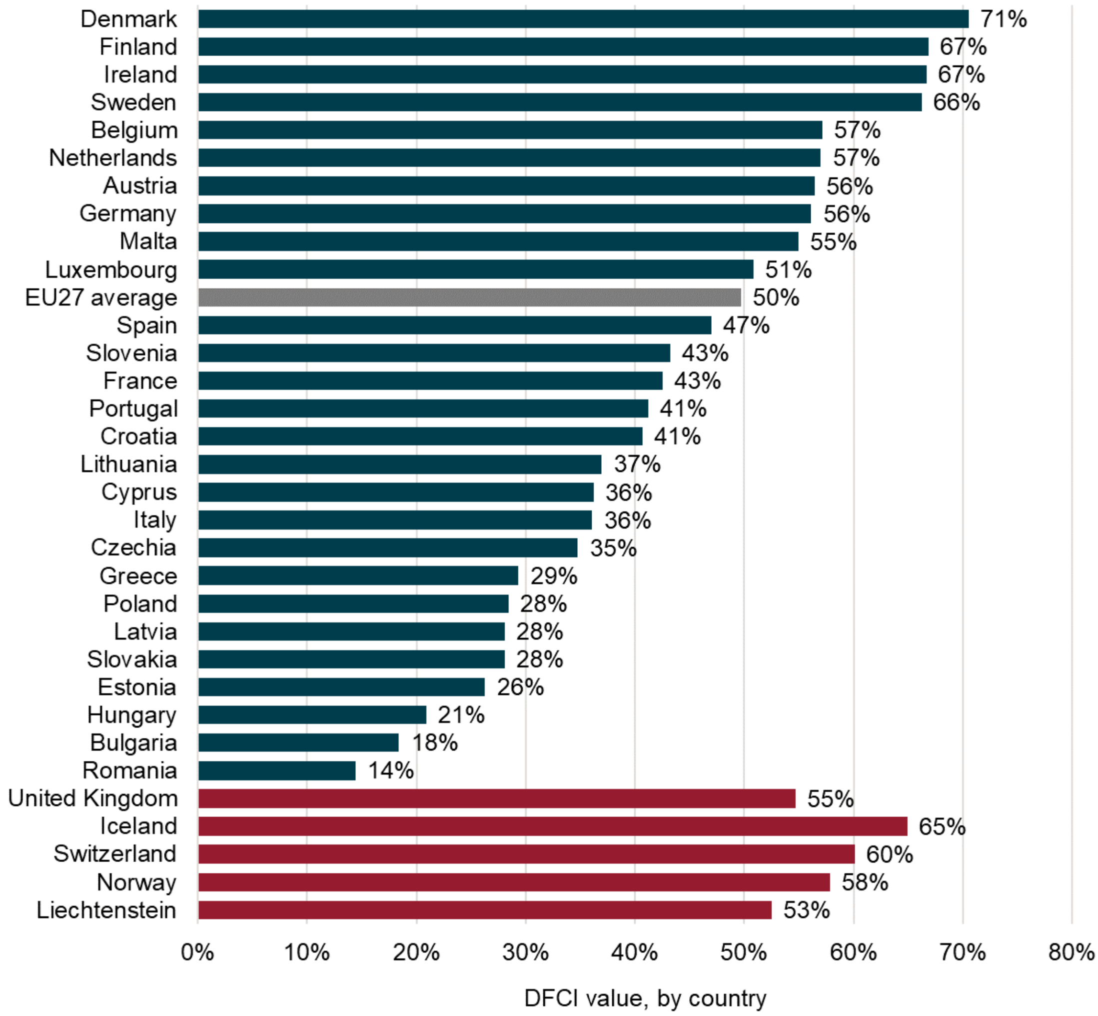
While all of the four countries at the top of the DFCI ranking (Denmark, Finland, Ireland and Sweden) generate significant volumes of ECBDFs, none of the four are among the countries with largest ECBDF volumes.[67] This supports one of the theoretical pillars of our approach, that is, that there is no linear relationship between the volume and value of ECBDFs.

Conversely, Romania, Bulgaria and Hungary are lowest in terms of DFCI value, below Estonia and Slovakia, the latter of which is nearly tied with Latvia and Poland.

66 Country-level DFCI values (e.g. DFCI value for Slovenia) are calculated as a weighted average of the DFCI values for each sector within each country (Slovenian manufacturing, Slovenian finance, …). The weights used in the calculation are our sector-level estimates of the value of cloud services to enterprises in that sector.

67 Neither in terms of the absolute volume of ECBDFs (PB/year), nor in terms of the volume relative to the size of a country's economy (PB per €m GVA).

Figure 4.2 Data Flow Criticality Index in 2023, by country



Note: Values are weighted averages of the underlying DFCI calculated at country-sector level.

The results above imply that around 50% of the enterprise user value of cloud-based services and of the profits of cloud service providers as estimated in this report can be attributed to ECBDFs in the EU. Given the difficulty of disentangling the value of ECBDFs from the value of cloud services and the novelty of our methodology, the DFCI should be interpreted as an approximate proxy. We recommend that the EU average figure of 50% is not interpreted too literally. However, this figure implies that optimal use of data flows contributes a significant proportion (potentially 50%) of the additional country-level GVA generated through enterprise use of cloud-based services.

Our methodology also includes estimating different DFCI values for "basic" cloud services, compared to "intermediate" and "sophisticated" services.[68] Indeed, based on our theoretical framework, we expect that the proportion of the user value of cloud services attributable to

[68] Basic cloud services are defined by Eurostat as using cloud for email, office software and file storage. Intermediate cloud services are defined by Eurostat as using cloud for enterprise resource planning software, customer relationship management software, or finance or accounting software applications. Sophisticated services are defined as use of cloud for security software applications, hosting for the enterprise's database, or a computing platform that provides a hosted environment for application testing, development or deployment. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Cloud_computing_-_statistics_on_the_use_by_enterprises#Cloud_computing_in_enterprises:_highlights

ECBDFs is lower in the case of “basic” services than in the case of “intermediate” and “sophisticated” services. This is because we expect ECBDFs to be less critical for enterprises to generate value (measured as GVA) from their use of basic cloud services compared to intermediate and sophisticated services. Our full reasoning is based on our conceptual framework presented in Chapter 1 and described in detail in the methodological note.

Our results show that the DFCI for intermediate/sophisticated services (53%) is about 50% higher than the DFCI for basic services (36%). **In other words, this means that around 53% of the user value of intermediate and sophisticated cloud services may be attributable to ECBDFs, compared to only 36% for basic services.**

The proportion of cloud services value attributable to ECBDFs varies not only between countries, enterprise size and cloud service types but also between sectors.[69]

Figure 4.3 below shows that, for the EU, the proportion of the value of cloud services to user enterprises attributable to ECBDFs is highest in the **information & communication** and **finance & insurance services** sectors (76% and 70%, respectively), followed by wholesale and retail trade (64%) and manufacturing (61%). On the other side of the spectrum, the **construction sector (30%), accommodation and food service, public administration and defence, human health and social work, and education have the lowest values.[70]** This pattern holds true across most European countries (24 out of 32 countries including EU Member States, UK and EFTA).

As in the case of country-level results, again sectors that have high DFCI values are not necessarily sectors with high ECBDF volumes. For example, the manufacturing sector generates a large volume of ECBDFs and also has a relatively high DFCI value, while the information and communications sector has a relatively small volume of ECBDFs (partly explained by its smaller overall size) but ranks highly in terms of DFCI (the criticality of the ECBDFs).

It is worth noting that, even where ECBDFs are estimated to account for a relatively small proportion of the value of cloud services (demand-side, supply-side or externalities), this proportion is still significant at nearly one-third (30% or higher).

We observe that these differences in sector-level DFCIs also contribute to the differences between countries reported earlier in this section, where countries with larger information & communication and financial & insurance activities sectors also have a higher country-level DFCI value. For example, in Denmark, the country with the largest DFCI value, the information & communication and financial & insurance activities sectors together account for 19% of GVA, well above the EU average of 10%. Similarly, those sectors account for 24% of GVA for Ireland, the country with the third-highest DFCI value.

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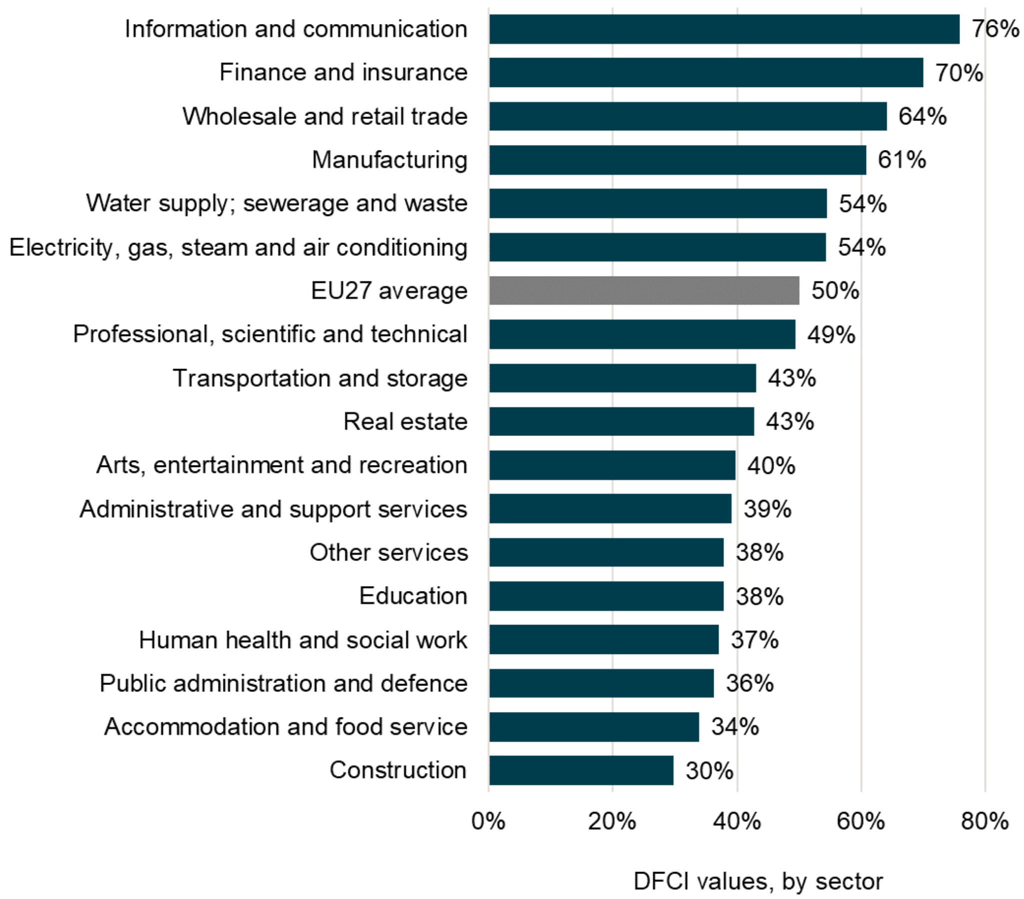
[69] Due to data availability, our sector-level analysis focuses on NACE codes C to S, excluding code A (agriculture), B (mining and quarrying) and T (activities of households as employers). This is because data on cloud uptake and on the components of the DFCI are not available for these sectors. These sectors combined account for less than 3% of EU GVA (source: Eurostat). Therefore, it is likely that our results would not change significantly if these sectors were included.

[70] Values for the public administration & defence, education, human health & social work, arts, entertainment & recreation, other service activities and administrative & support services sectors are all very similar. This is due to limitations in the available data for sectors with NACE codes O to S for two out of the three DFCI drivers, where these sectors took the DFCI values of sector N for those drivers. “Other service activities” includes hairdressing & other beauty treatment, physical well-being activities, and funeral & related activities, among others.

Figure 4.3 Data Flow Criticality Index in 2023, by sector (NACE codes C to S)



Note: "Other services" includes activities of membership organisations; repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles; personal service activities; and activities of households as employers of domestic personnel.

The next sections of this chapter show our estimates of demand-side value, supply-side value and externalities from ECBDFs that rely on the DFCI values presented above.

c. The economic value of ECBDFs to cloud users (demand-side impact)

As described in Chapter 2 and earlier in this chapter, to estimate the demand-side value of ECBDFs, we multiply the country-sector level DFCI by our estimate of the additional GVA that each enterprise generates as a result of its use of cloud services for each country-sector pair ("user value of cloud services"). The DFCI is used to disentangle the specific value of the ECBDFs from the broader user value of cloud services.

The box below provides a practical example of our calculation of the value of ECBDFs to cloud-using enterprises.

The remainder of Section 4.c is structured as follows. In Section 4.c.i, we begin by presenting our best estimates for the value of ECBDFs in 2023, which is the most recent year for which we have data available. We then show our estimates of the value of cloud services to cloud-using enterprises in section 4.c.ii. In section 4.c.iii, we report our high-level estimates of the value at stake from ECBDFs between Europe and other regions. Finally, in section 4.c.iv we report our forecasts for 2024 (the year of publication of this report), 2025, 2030 and 2035 (which are key milestones for various EU policies and strategies in the digital space) in Section 3.b.ii. Our estimates for 2023, 2024 and future years include a breakdown by country, sector, types of cloud services used ("basic" versus "intermediate" and "sophisticated" according to Eurostat's classifications), and enterprise size (SMEs vs large enterprises).

A practical example of the value of ECBDFs to cloud users

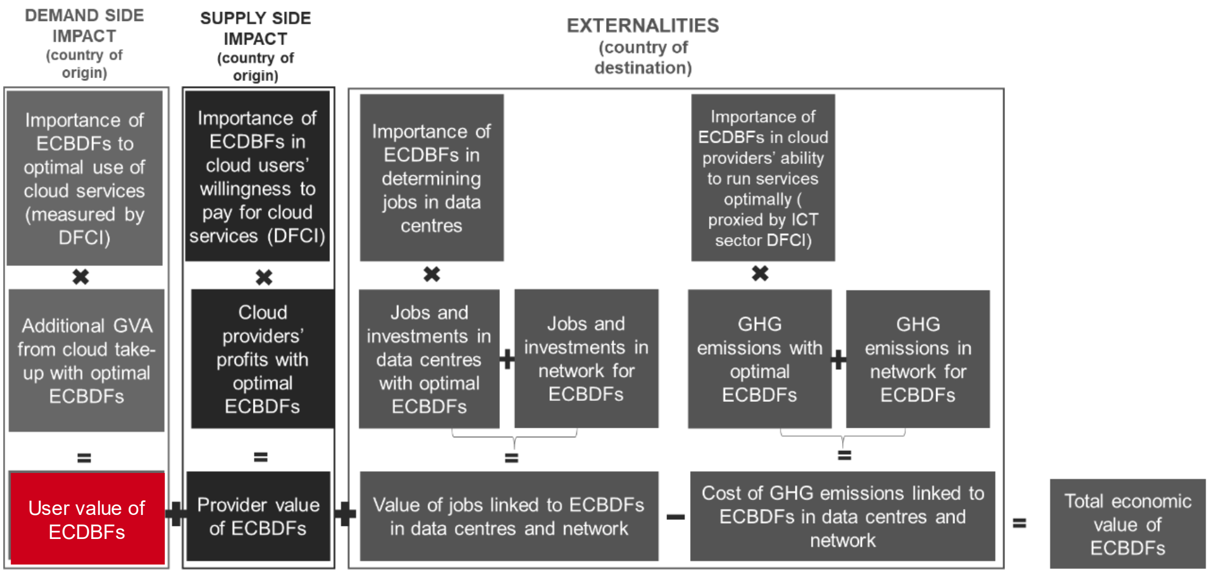
- Let us go back to our example of a large Spanish manufacturing enterprise (SPAMA) and a small Belgian investment enterprise (BELFIN) from Chapters 1 and 2. We can apply our methodology to estimate the approximate value of ECBDFs to these enterprises.
- We know that the annual GVA generated by SPAMA in 2023 is €500m and the GVA generated by BELFIN in the same year is €50m. We also know that the percentage of enterprises that use cloud services in the Spanish manufacturing sector is 30% and the same percentage in the Belgian finance sector is 50%. Our calculation would involve the following steps.
- Firstly, we estimate the additional GVA that each enterprise generates as a result of its use of cloud services ("user value of cloud services"). We multiply the GVA generated by each of these enterprises by the percentage impact of cloud on firm GVA (0.9%), by applying estimates from existing evidence (Gal et al. 2019). We find that the additional GVA generated by SPAMA and BELFIN as a result of cloud use is (€500m * 0.9% = €4.5m) and (€50m * 0.9% = €0.45m) respectively.
- Then, we estimate the proportion of the enterprise user value of cloud services attributable to ECBDFs. We do this by calculating and applying the DFCI at the country-sector level, i.e. in this example we do it for Spanish manufacturing. Our calculations show that the DFCI for the Spanish manufacturing sector is 25%, while for the Belgian finance sector it is 40%. This results from the fact that Spanish manufacturing firms are less likely than Belgian finance firms to require ECBDFs to access their customers, and are also less likely to use cloud-based capabilities that require a minimum scale of ECBDFs to be used efficiently (while Spanish manufacturing firms and Belgian finance firms are equally likely to require ECBDFs to build and benefit from secure cloud architectures).
- Finally, applying the DFCI to SPAMA and BELFIN indicates that the likely value of ECBDFs for these enterprises in 2023 is €1.125m (25% of SPAMA's €4.5m user value of cloud services) and €180,000 (40% of BELFIN's €0.45m) respectively for SPAMA, and BELFIN.

It is important to note that both the calculation of enterprise user value of cloud services and the calculation of the DFCI rely on a number of assumptions, set out in detail in Section 3 of the methodological note accompanying this report. These assumptions are needed due to the limitations of available data and the conceptual complexity involved in attempting to separate the value of ECBDFs from the value to users of cloud services, when these are inextricably intertwined.

Due to the number of assumptions involved, we have greater confidence in interpreting how the relative values of ECBDFs and the value of cloud services vary across countries, sectors and firms sizes (e.g. "Germany generates twice as much value from ECBDFs compared to Italy"), as opposed to interpreting their absolute values (e.g. "the value of ECBDFs in Germany is €16.3bn").

We estimate the value of cloud services by combining estimates from studies of the effect of cloud services on business multi-factor productivity with data on the cloud uptake and GVA generated by European enterprises, depending on their sector, country, types of cloud services used ("basic" versus "intermediate" and "sophisticated" according to Eurostat's classifications) and size (SMEs vs large enterprises).[71]

i. Total enterprise user-side economic value of ECBDFs



We estimate that the total annual value of ECBDFs to enterprises that use cloud services (the demand-side impact) in the EU in 2023 was **€59bn**. To put this into context, this is around the same size as the total annual GDP of Slovenia.[72] The total annual value for the UK was €17bn and the value for EFTA countries was €7bn.

For the EU, the estimated value of ECBDFs is approximately 50% of the total enterprise user value of cloud services (€118bn). While this figure should be interpreted with caution, due to the difficulty of separating the intertwined value of ECBDFs and user value of cloud services, it clearly indicates that ECBDFs play a very important role in the value that enterprises generate from their use of cloud services.

Our results also provide estimates of how this role varies between countries, sectors, firm sizes and types of cloud services.

Figure 4.4 and Figure 4.5 below present the € value of ECBDFs that originate from each country in this report, and as a proportion of the total GVA generated in each country.

The countries with the largest user-side economic value of ECBDFs are the UK (€17.2bn) and Germany (€16.3bn), followed by Italy (€7.4bn), Netherlands (€5.6bn), Sweden (€4.9bn), Ireland (€4.4bn) and France (€3.8bn).

In line with the methodology described in Chapter 1, the relative position of each country in user-side economic value of ECBDFs depends on:

- The effect of cloud services on business GVA in the country, measured as the percentage uplift in GVA ("cloud % GVA impact");

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71 Eurostat classifies email, office software and data storage cloud services as "basic" cloud services, while all other cloud services are classified as "intermediate" or "sophisticated".

72 Which is €57bn according to the latest figures available from Eurostat (for the year 2022).

- The proportion of this impact that is attributable to ECBDFs (as proxied by our DFCI index); and
- The size of a country's economy, as measured by its GVA.[73]

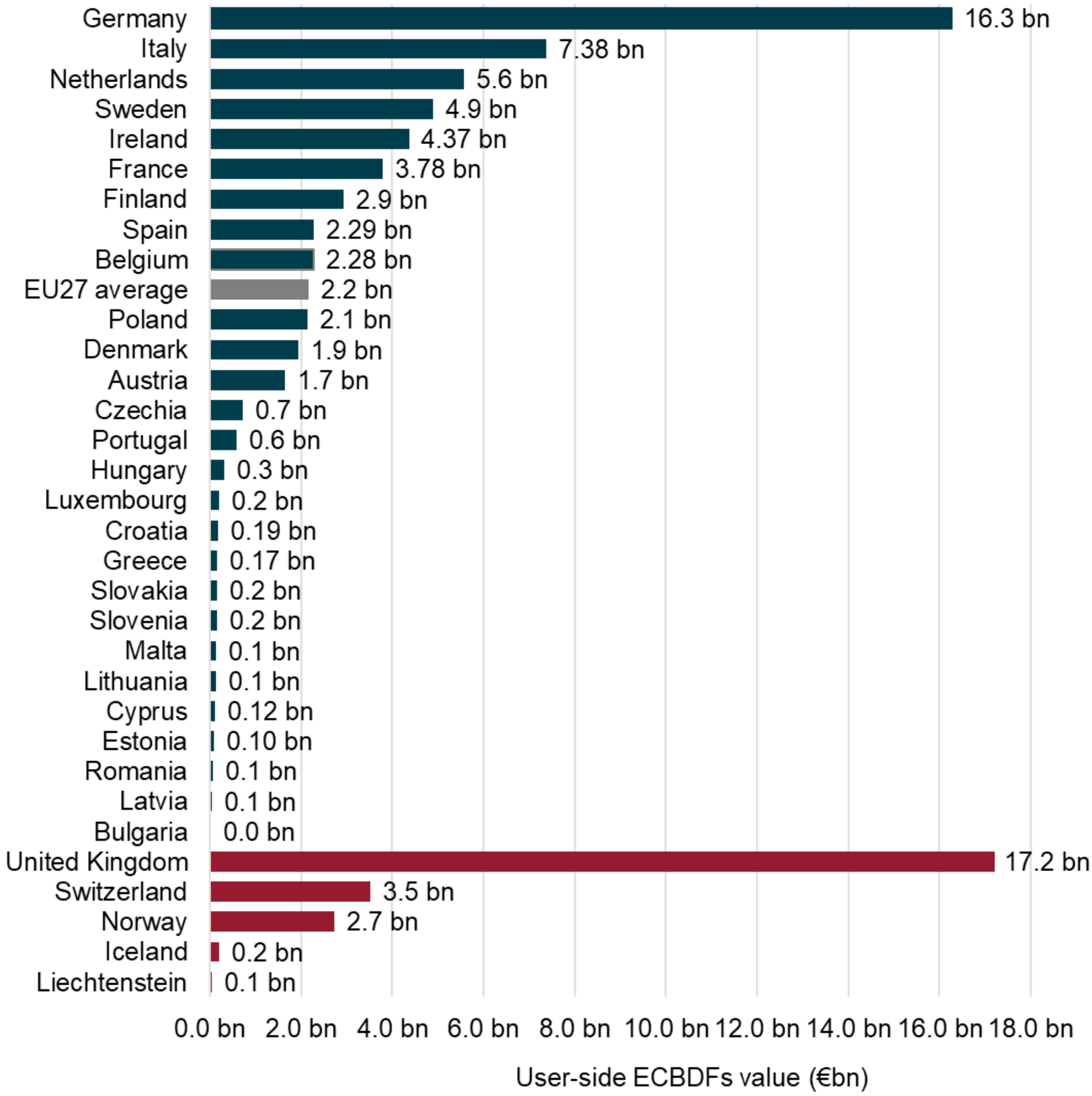
This can be seen by considering the countries with the highest value of ECBDFs. For example, the UK has the second-highest GVA in Europe for 2023, as well as one of the highest cloud uptakes and a DFCI above the European average.

Germany is the largest economy in Europe, with a value of ECBDFs that is second-highest only to the UK, despite it being close to the EU average both in terms of the impact of cloud services on GVA and in terms of its DFCI. Conversely, the Netherlands and Sweden are smaller economies, but their relatively high values of ECBDFs are driven by above-average figures for the impact of cloud services and their DFCI.

Besides Germany, the Netherlands and Sweden, the top five countries in Europe in terms of user-side ECBDF value include Italy and Ireland (followed closely by France). Conversely, the bottom five countries in the EU are Bulgaria, Latvia, Romania, Estonia and Cyprus. This is primarily due to the smaller size of their economies compared to other countries in the EU.

[73] Because these components are multiplied to estimate the value of ECBDFs, a doubling of each of the components would lead to a doubling of the estimated ECBDF value.

Figure 4.4 User-side value of ECBDFs in 2023, by country

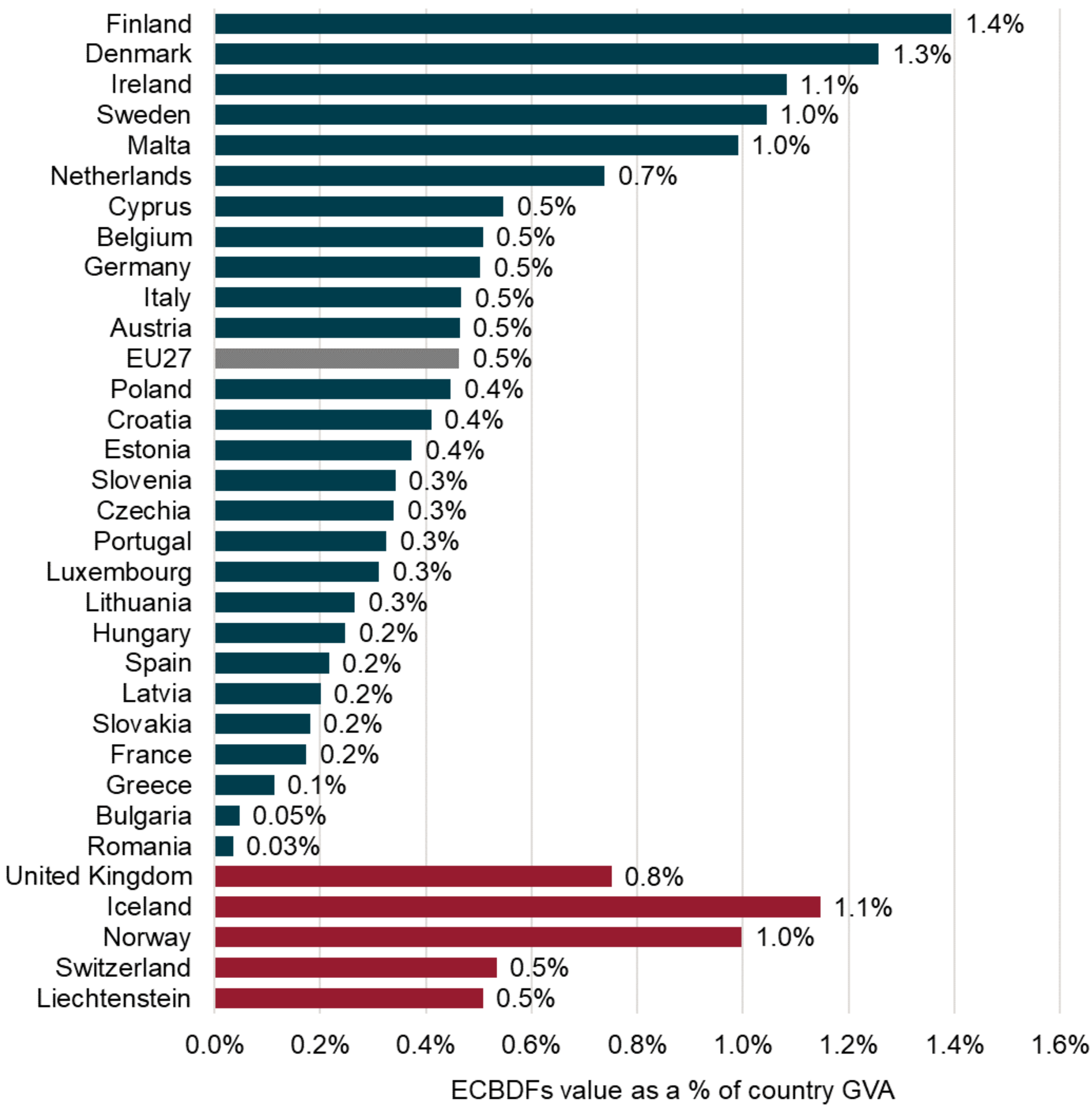


On average across EU Member States, the user-side value of ECBDFs is around 0.5% of Member States' GVA.[74] For context, the entire information and communication sector in the EU accounts for around 2% of the total EU GVA under analysis in this chapter.

When we look at the user-side of ECBDFs compared to the country's GVA (Figure 4.5 below), the ranking shown above changes significantly. Finland, Sweden, Denmark, Ireland and the Netherlands have the highest figures for ECBDFs as a proportion of country GVA (as shown in the figure below). On the other hand, Bulgaria and Romania remain among the countries at the bottom of the ranking, but France, Greece and Slovakia are now also in the bottom five. This is due to the relatively low uptake of cloud services in these three countries (below EU average) and the relatively low criticality of ECBDFs as measured by the DFCI (also below EU average).

[74] As discussed in Chapter 2, we use GVA rather than GDP because GVA is the more appropriate and readily available metric for firm- and sector-level analysis. GVA at country level is a close proxy for country GVA.

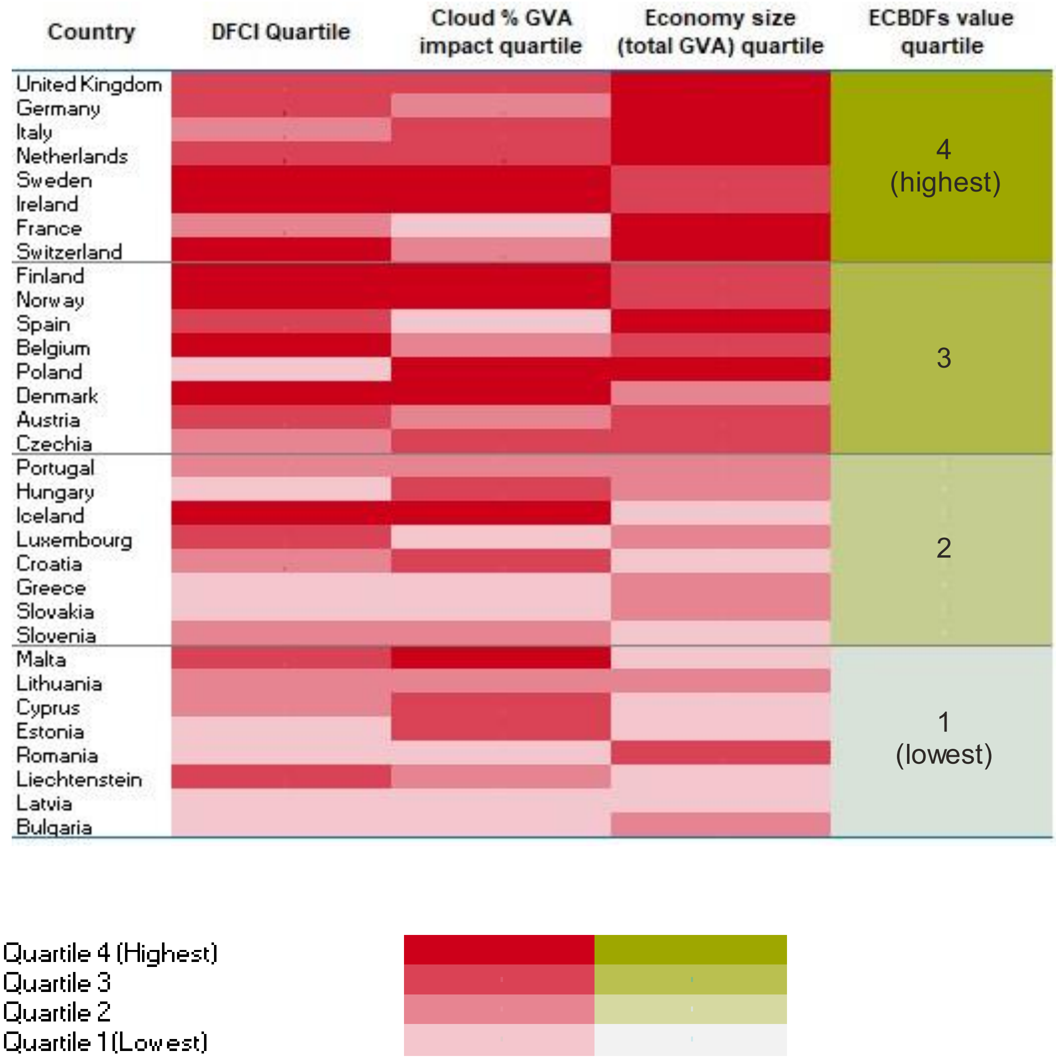
Figure 4.5 User-side ECBDFs value as a % of GVA in 2023, by country



The heatmap in Figure 4.6 below shows how the DFCI, cloud % GVA impact and total country GVA influence the overall position of each European country relative to others in terms of ECBDF demand-side value. The heatmap has segmented the values of each column into quartiles, with the highest values (quartile 4) in a darker shade, through to the lowest values (quartile 1) in a lighter shade. Countries are also ranked within each quartile.

The heatmap shows that the countries with highest ECBDFs demand-side value (the top eight) can be divided into two groups: on the one hand, economies with a high DFCI score (UK, Germany, the Netherlands, Sweden, Ireland, Switzerland); on the other, Italy and France, which despite their lower DFCI score have nevertheless a high value of ECBDFs due to the overall size of their economy. Among other countries, it is interesting to note where the cloud % GVA impact and DFCI values are not fully aligned. For example, we can see that enterprises in the Netherlands draw a relatively high value from cloud services (top quartile), but their use of cloud services is less reliant on ECBDFs compared to Sweden (which is in the top quartile both in terms of DFCI and cloud % GVA impact).

Figure 4.6 The distributions of ECBDF value and key inputs in 2023, by country



Figures 4.7 and 4.8 below present the demand-side value of ECBDFs by the sector of the enterprises that trigger them (across Europe as a whole), and the same value as a percentage of sector GVA.

As with our country-level results, the sectors with the largest ECBDF value also tend to have larger GVA, meaning that sectoral GVA is a key driver of sector-level ECBDF value. In particular, manufacturing, the sector with the highest value of ECBDFs (€11.4bn), also has the highest GVA (€2.3tn). However, as manufacturing does not have the highest DFCI or the highest cloud uptake among all sectors, it ranks third when we look at the user-side value of ECBDFs as a proportion of sector GVA (Figure 4.8).

However, information & communication also has a high ECBDF value (€8.0bn), which is partly driven by its higher DFCI value (76%, which means that around 76% of the total user value of cloud services in the sector could be attributed to ECBDFs). Unsurprisingly, this leads to ECBDFs accounting for the highest proportion of GVA in the information & communication sector (1.0%).

Figure 4.7 User-side value of EU ECBDFs in 2023, by sector (NACE codes C to S)

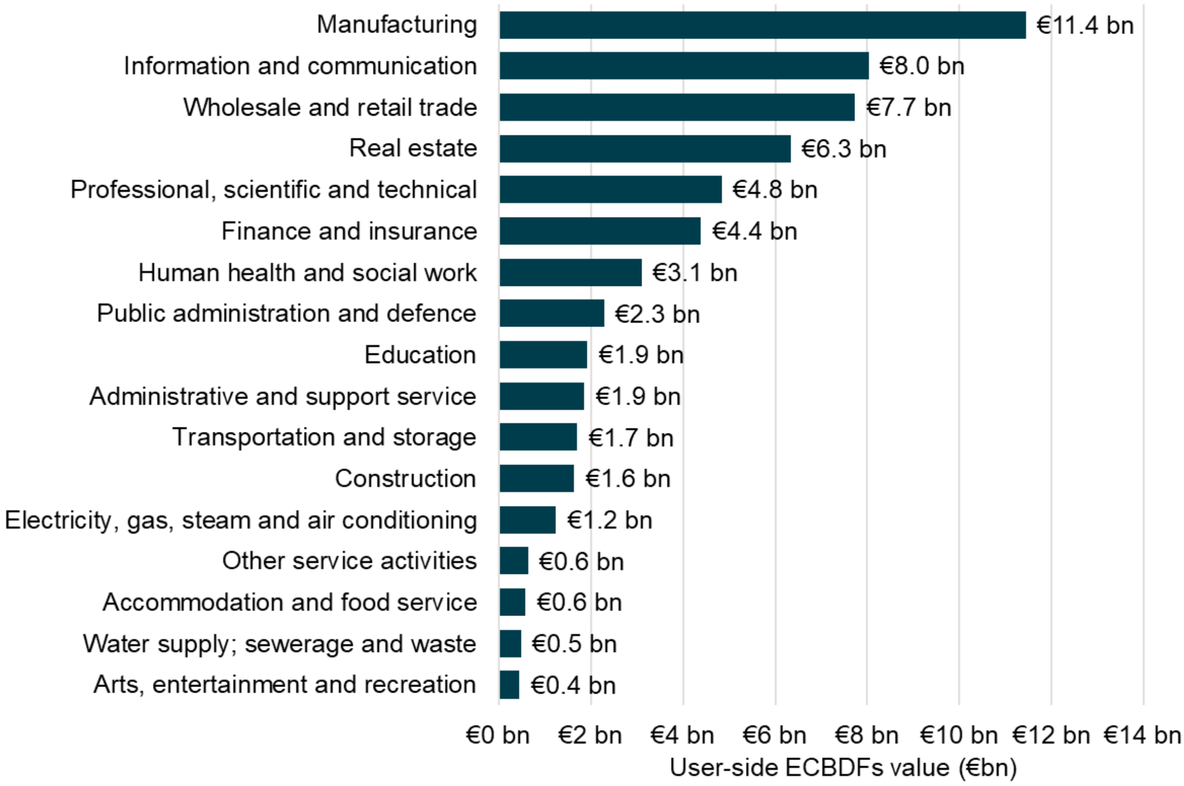


Figure 4.8 EU user-side ECBDFs value as % of GVA in 2023, by sector (NACE C to S)

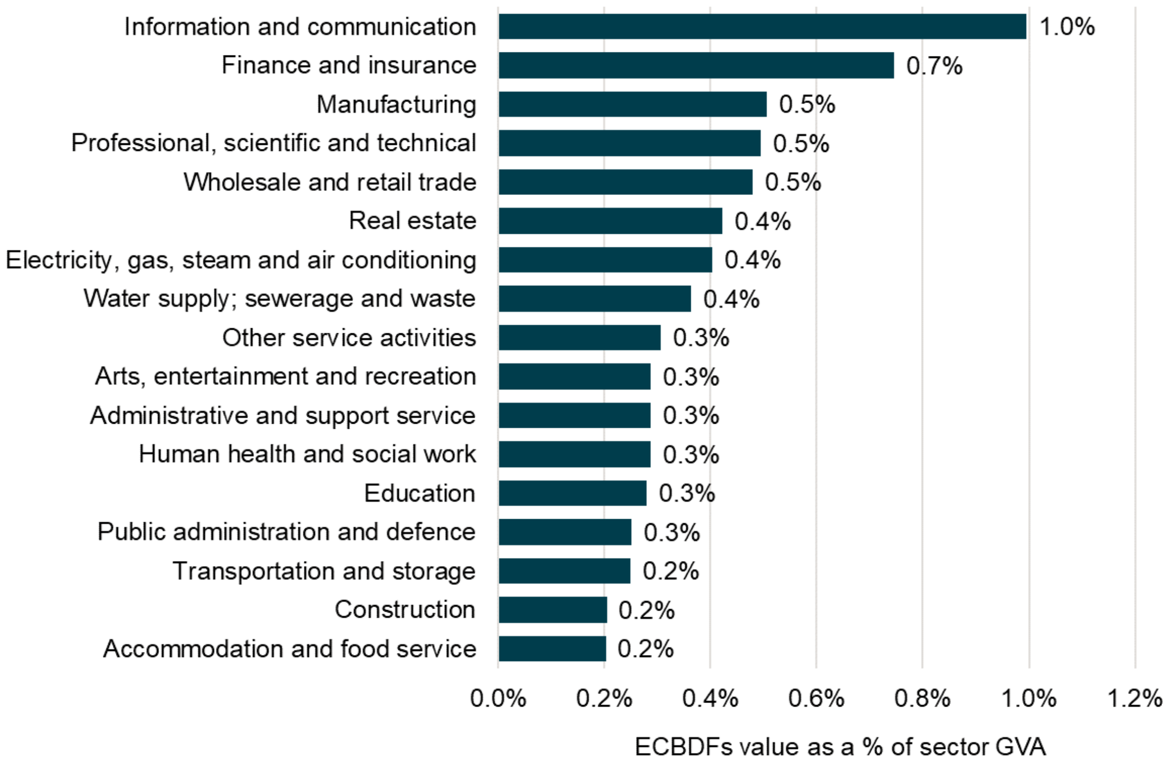


Table 4.2 and Figure 4.9 below present the user-side value of ECBDFs split by large enterprises (250 or more employees) and SMEs (under 250 employees).

Table 4.2 User-side value of ECBDFs by firm size, 2023

Geography	User-side value of ECBDFs originating from SMEs (€bn)	User-side value of ECBDFs originating from large enterprises (€bn)	Total user-side value of ECBDFs (€bn)
EU	29.2 bn	29.5 bn	58.6 bn
EFTA	3.6 bn	2.9 bn	6.5 bn
UK	7.8 bn	9.4 bn	17.2 bn
Europe total	40.6 bn	41.8 bn	82.4 bn

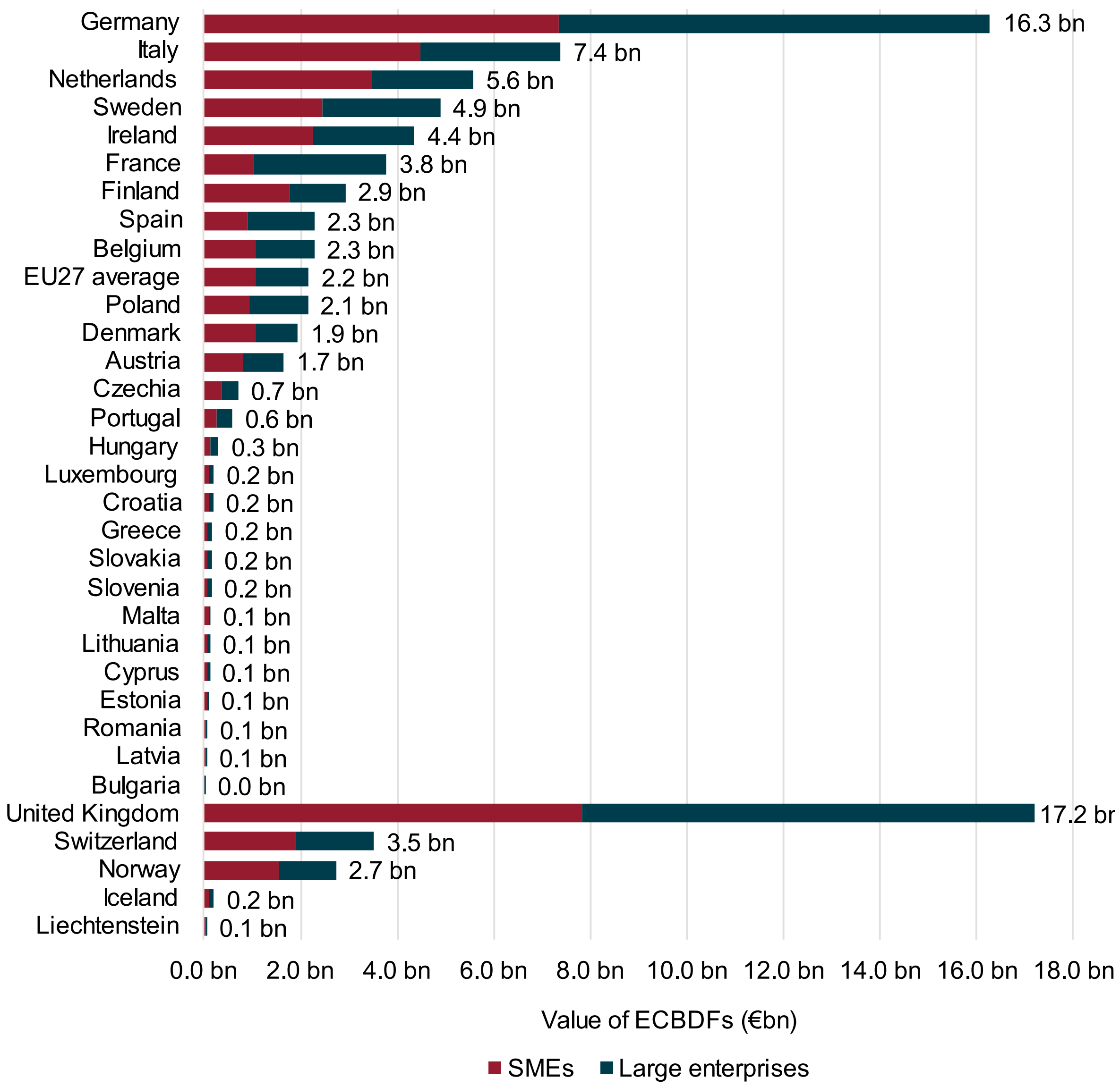
Across all countries (including EU, EFTA and UK) SMEs account for 49% of the demand-side value of ECBDFs (€40.6bn), compared to 51% (€41.8bn) for large enterprises.[75] SMEs account for approximately the same user-side value of ECBDFs, despite cloud uptake being lower among SMEs compared to large enterprises (44% on average for SMEs compared to 78% for large firms).[76] This is due to the fact that cloud uptake has a greater impact on the GVA of SMEs compared to large companies – and therefore, the impact of ECBDFs in enabling firms to extract value from cloud services is particularly important for SMEs.[77]

75 Data on the GVA of SME/large businesses separately for each country-sector pairing is not directly available from Eurostat.

76 SMEs also account for approximately 50% of EU GVA.

77 Gal et al. (2019) find that the impact of cloud uptake for SMEs is approximately 2.7 times the impact for large enterprises.

Figure 4.9 User-side value of ECBDFs in 2023, by country



As shown in Figure 4.9 above, SMEs account for a particularly high proportion of total ECBDF value in Italy and the Netherlands. This is due to SMEs accounting for a relatively high proportion of GVA in Italy and the Netherlands (62% and 64% respectively, compared to the EU average of 52%). Conversely, the proportion of user-side value accounted for by SMEs is particularly low in France. This is due to the particularly low uptake of cloud services among French SMEs compared to the EU average (French SMEs are half as likely as the average EU SME to use cloud services, according to latest data from Eurostat).

We also estimate the value of ECBDFs that originate specifically from firms that use only "basic" cloud services (as defined by Eurostat – including use of cloud for email, office software and file storage). This amounts to €4.5bn in EU, or 8% of the total user-side economic value of ECBDFs.

"Non-basic only" cloud use therefore accounts for the remaining 92% of user-side ECBDF value in EU, or €54.1bn. This category of cloud service usage consists of "intermediate" (related to use of software applications such as CRM, Enterprise Resource Planning or finance applications) and "sophisticated" (related to use of security software applications, hosting either for websites or application development) services.[78]

Table 4.3 below presents the breakdown of user-side ECBDF value between "basic" cloud use and "non-basic" cloud use, across all countries. Austria and Poland stand out for having a higher proportion of total user-side value of ECBDFs accounted for by the use of basic cloud services (11% and 14% respectively, compared to an EU average of 7%). This is due to the fact that adoption of basic cloud services accounts for a particularly high proportion of overall cloud usage. Conversely, this proportion is particularly low in Denmark, the Netherlands and Sweden.

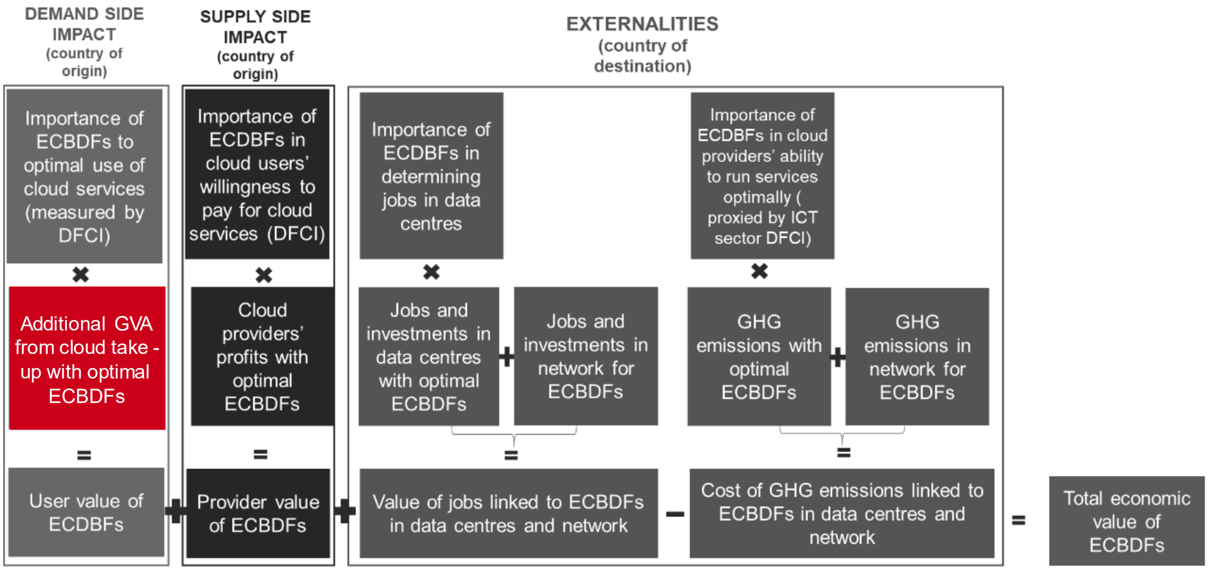
Table 4.3 User-side value of ECBDFs in 2023, by cloud service and country

Country	Basic only services (€bn)	Non-basic only ("Intermediate"/ "Sophisticated") services (€bn)	Total value of ECBDFs (€bn)
Germany	1.70 bn	14.6 bn	16.3 bn
Italy	0.49 bn	6.9 bn	7.4 bn
Netherlands	0.19 bn	5.4 bn	5.6 bn
Sweden	0.21 bn	4.7 bn	4.9 bn
Ireland	0.36 bn	4.0 bn	4.4 bn
France	0.30 bn	3.5 bn	3.8 bn
Finland	0.11 bn	2.8 bn	2.9 bn
Spain	0.13 bn	2.2 bn	2.3 bn
Belgium	0.12 bn	2.2 bn	2.3 bn
EU average	0.17 bn	2.0 bn	2.2 bn
Poland	0.24 bn	1.9 bn	2.1 bn
Denmark	0.05 bn	1.9 bn	1.9 bn
Austria	0.23 bn	1.4 bn	1.7 bn
Czechia	0.13 bn	0.59 bn	0.71 bn
Portugal	0.04 bn	0.54 bn	0.59 bn
Hungary	0.04 bn	0.27 bn	0.31 bn
Luxembourg	0.01 bn	0.19 bn	0.20 bn
Croatia	0.01 bn	0.18 bn	0.19 bn
Greece	0.03 bn	0.14 bn	0.17 bn
Slovakia	0.01 bn	0.14 bn	0.16 bn
Slovenia	0.01 bn	0.14 bn	0.15 bn
Malta	0.01 bn	0.13 bn	0.14 bn
Lithuania	0.01 bn	0.12 bn	0.13 bn
Cyprus	0.01 bn	0.11 bn	0.12 bn
Estonia	0.01 bn	0.09 bn	0.10 bn
Romania	0.01 bn	0.06 bn	0.07 bn
Latvia	0.01 bn	0.05 bn	0.06 bn
Bulgaria	0.002 bn	0.02 bn	0.03 bn
United Kingdom	1.3 bn	16.0 bn	17.2 bn
Switzerland	0.30 bn	3.2 bn	3.5 bn
Norway	0.07 bn	2.7 bn	2.7 bn
Iceland	0.01 bn	0.20 bn	0.21 bn

[78] We split basic versus non-basic (intermediate and sophisticated cloud services) because our conceptual framework (described in chapter 1 of this report and in further detail in the accompanying methodological note) suggests that the proportion of value attributable to ECBDFs is higher for intermediate & advanced cloud services than for basic cloud services. We do not distinguish between intermediate and sophisticated services because the framework does not suggest that ECBDFs are more important for sophisticated services compared to intermediate services, from a theoretical perspective.

Liechtenstein	0.004 bn	0.05 bn	0.06 bn
Total EU	**4.49 bn**	**54.14 bn**	**59.6 bn**
Total EFTA	0.38 bn	6.15 bn	6.5 bn
Total Europe	6.1 bn	76.25 bn	82.4 bn

ii. Estimated value of cloud services to user enterprises



The user-side values of ECBDFs presented above rely on our estimates of the DFCI (described in Section 3.a) and our estimates of the value of cloud services to enterprises using cloud-based capabilities. We report our estimates of the value of cloud services to user enterprises in this section.

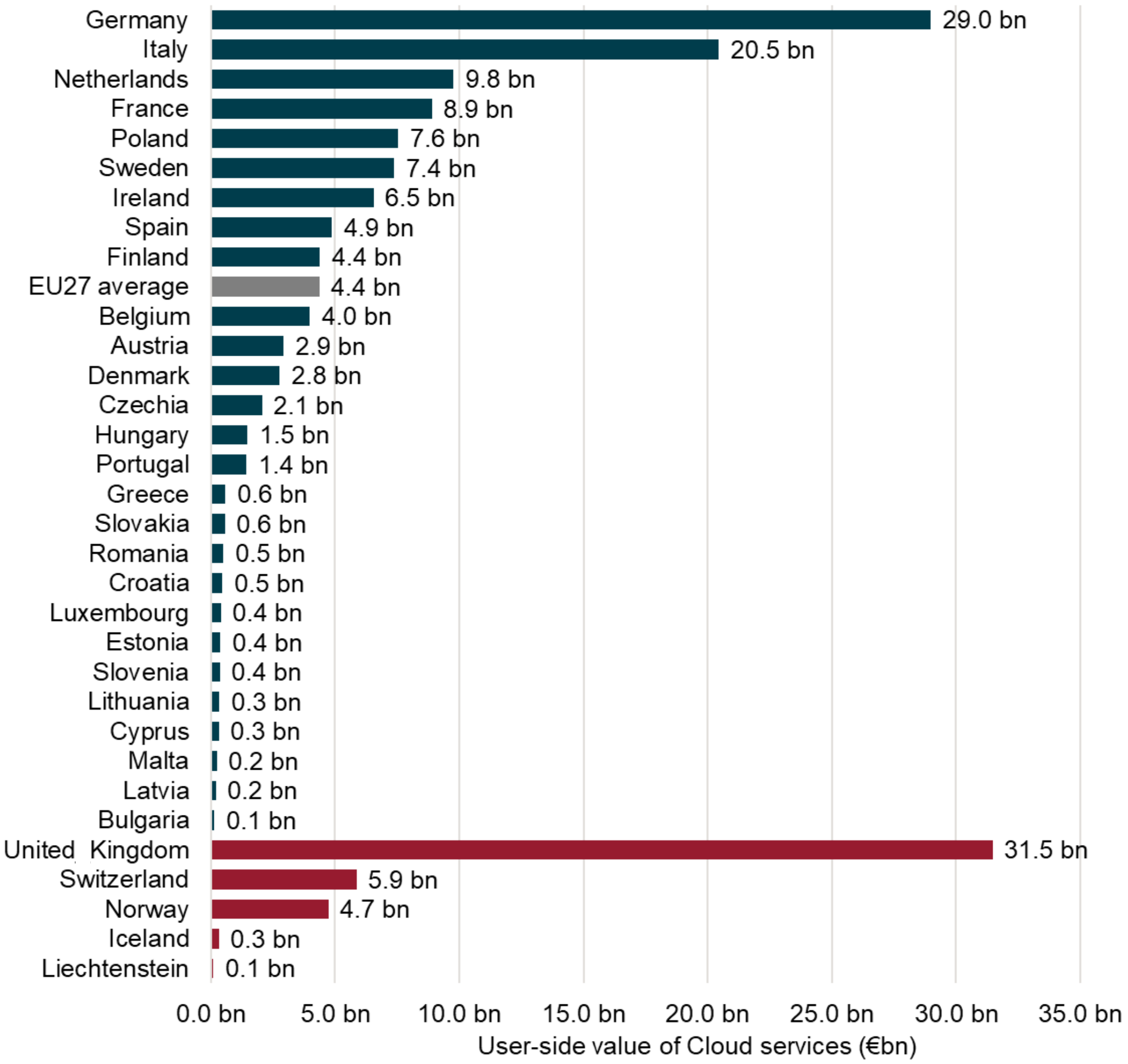
Specifically, we estimated the additional GVA generated by enterprises as a result of their cloud use, compared to a counterfactual where all else remains the same with the exception that the enterprise does not use cloud services. Comparing the current "factual" state to this counterfactual helps us separate out the economic value that stems from the use of cloud services, expressed in terms of additional GVA.

We find that for the EU as a whole, the use of cloud services is likely to enable additional €118bn in value generated per year. For the UK, the total value per year is €31bn, and for EFTA countries it is €11bn.

Figure 4.10 shows how the estimated value of cloud services varies between different countries in our sample. The relative position of a country in this chart is higher if:

- The country has a higher GVA (as a result of a larger and/or more productive economy);
- The country has higher cloud adoption; and/or
- Our estimate of the percentage impact of cloud service use on firm GVA, generated through modelling based on the Gal et al. (2019) study, is higher.

Figure 4.10 Value of cloud services to cloud-using enterprises in 2023, by country

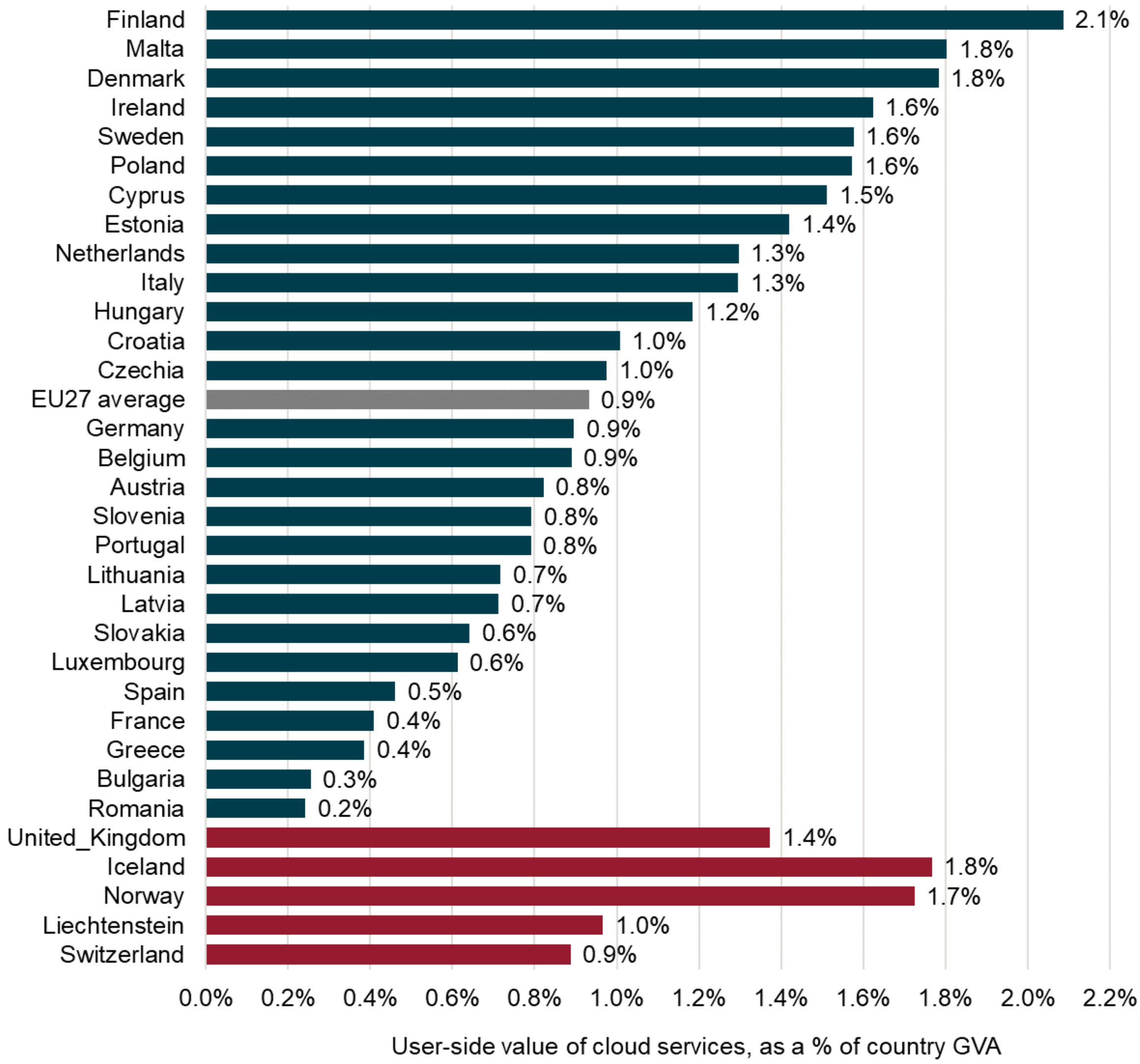


The UK has the highest value of cloud services, due to the combination of the UK's economy size (third-largest GVA in Europe) and relatively high cloud uptake (66%[79] in 2021). Germany's large value of cloud services is primarily driven by the overall size of its economy, which means that a large amount of GVA is produced by its cloud-using enterprises. Conversely, the Netherlands are fourth out of the EU Member States in this chart because, although its GVA is much smaller than Germany's (as a result of a smaller population and economy), the effect of cloud services on its GVA is relatively large. We can more easily compare countries of

[79] UK cloud uptake in 2021 is not available from Eurostat. We estimated this figure by combining UK sector-level cloud uptake historical estimates with their relativity to sector estimates in other comparator European countries (Germany, Ireland, Netherlands). As a cross-check, this UK cloud uptake in 2021 is not hugely out of line with the Netherlands figure (65%), which is consistent with the historical ratio between the UK and Netherlands; in 2020, UK cloud uptake from Eurostat was 53%, whereas the Netherlands was 53%.

different sizes by looking at the value of cloud services as a proportion of the country's GVA, as shown in Figure 4.11 below.

Figure 4.11 Value of cloud services to cloud-using enterprises as a proportion of total country GVA, 2023



For example, Finland ranks highest on this metric, with cloud services estimated to add value equivalent to 2.1% of the country's GVA. This is due primarily to the country's high uptake of cloud services (78% of firms with ten or more employees according to latest Eurostat data, compared to 45% on average in the EU). The high prevalence of SMEs in Finland (accounting for 59% of GVA, compared to 52% in the EU) also contributes to this result, as cloud services have been estimated to have a greater impact on SMEs compared to larger firms (Gal et al. 2019).

A relatively high uptake of cloud services also explains why the value of cloud services to users as a proportion of GVA is relatively high in other Nordic countries (Sweden, Denmark, Norway, Iceland), as well as in Malta, Poland and Cyprus, all of which had a fast rise in cloud uptake between 2018 and 2023. Conversely, EU countries further down this chart have cloud uptake below EU average: this includes, for example, Romania (18% cloud uptake), Bulgaria (18% cloud uptake), France and Spain (27% and 30% respectively).

We also estimated how the value of cloud services varies not only by country but also by sector, as shown in Figure 4.12 below. There is significant variation in the value of cloud services across sectors in 2023, from €0.9bn in water supply, sewerage & waste management through to €19.6bn in manufacturing. As reported earlier, for the EU as a whole, the use of cloud services is likely to enable additional €118bn in value generated per year.

Further below, Figure 4.13 presents the value of cloud service use in each sector as a proportion of the sector's GVA. The largest value is for information & communication (1.1%), followed by finance and insurance. This is driven primarily by the high uptake of cloud services in these two sectors compared to others.

Figure 4.12 EU GVA generated by cloud services in 2023, by sector (NACE C to S)

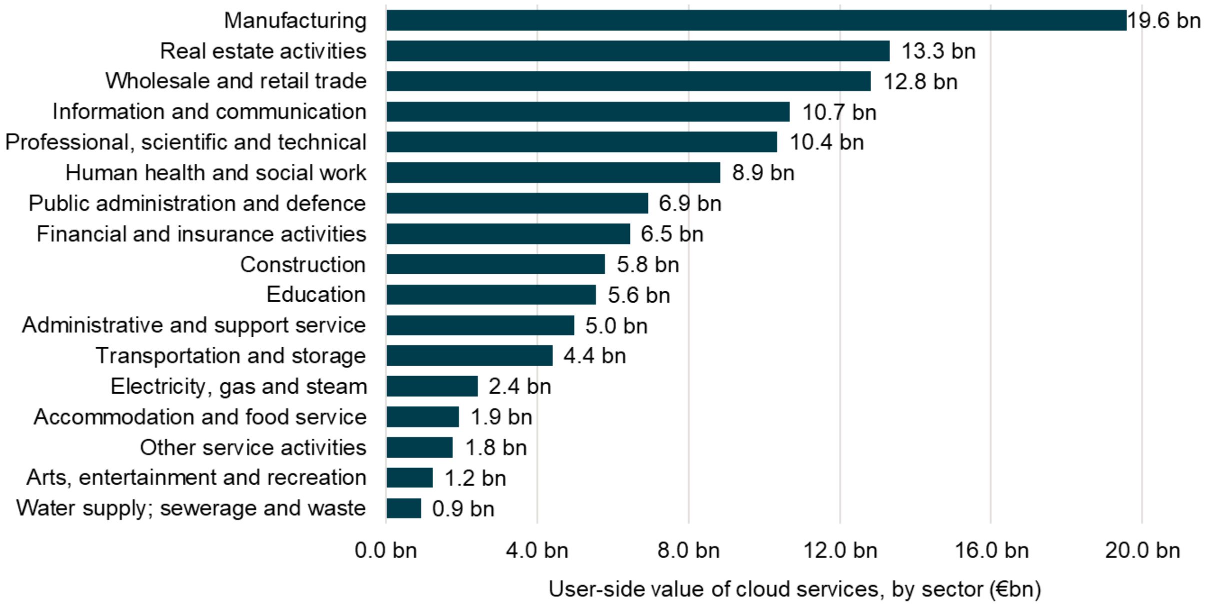
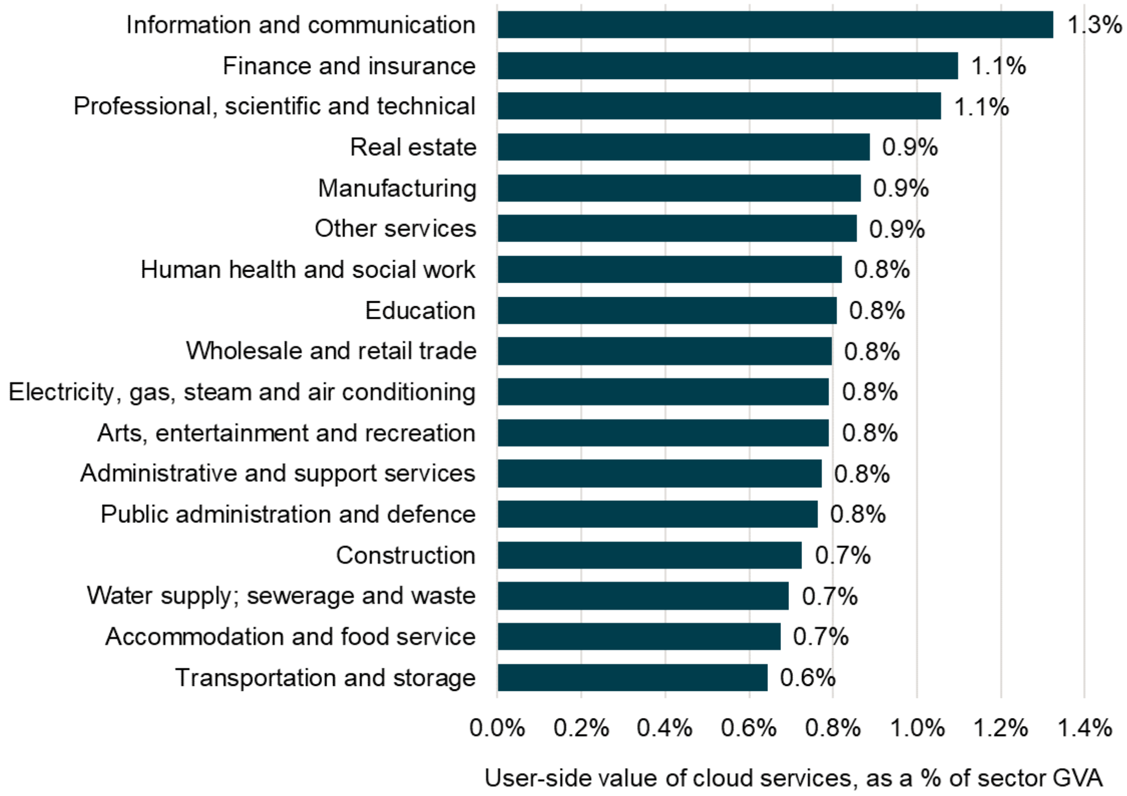


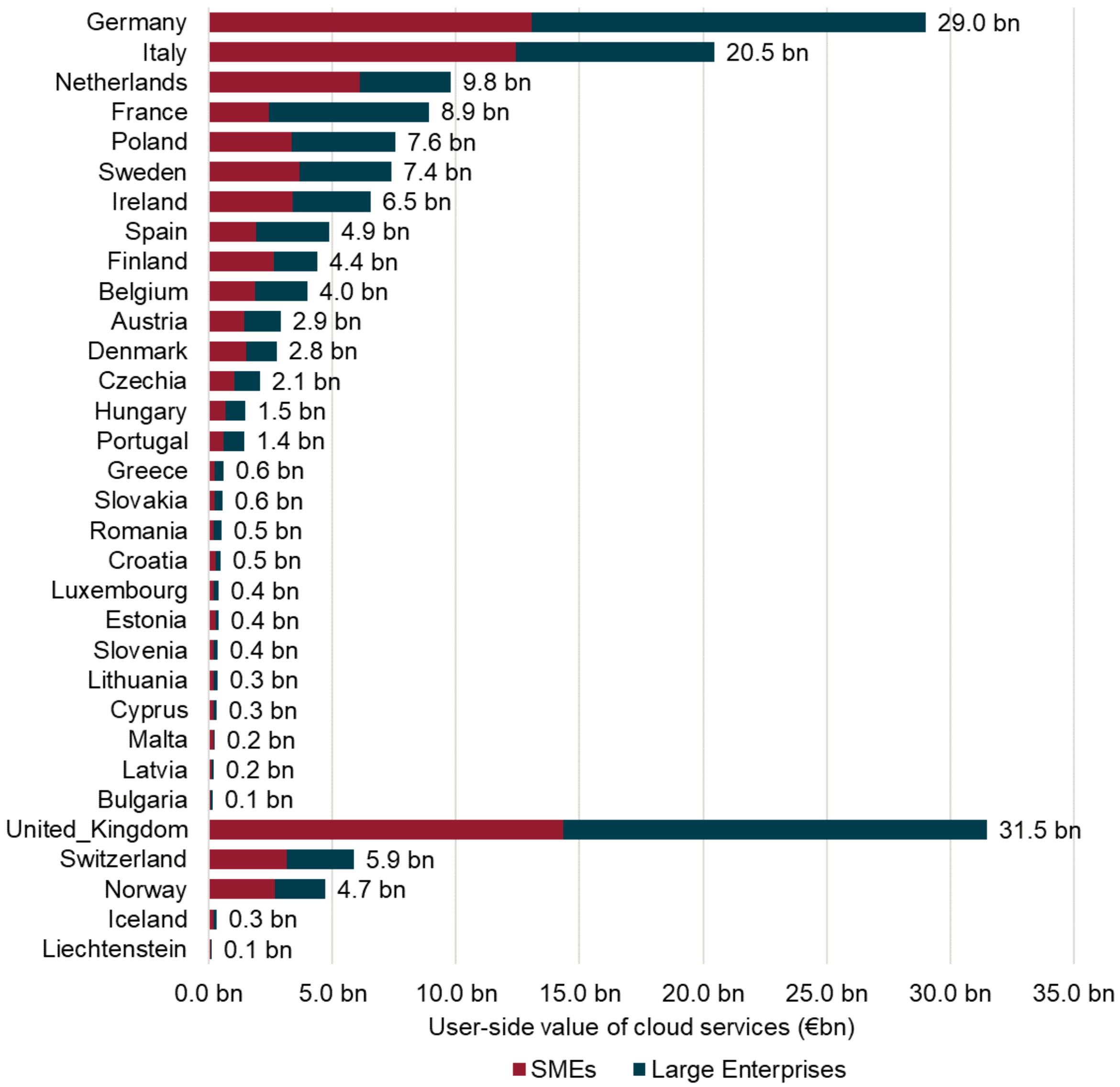
Figure 4.13 Cloud services value as a proportion of GVA, by sector (NACE C to S)



We also estimate how the value of cloud services to users varies by firm size. As mentioned above, Gal et al. (2019) estimate that the impact of cloud services on enterprises that use them is substantially higher for SMEs than for large firms.

Therefore, while SMEs have significantly lower cloud uptake than large enterprises, they actually account for approximately 50% of the user-side value of cloud services estimated in this report (49% across the EU as a whole). As mentioned above, the prevalence of SMEs is relatively high in Finland, and indeed SMEs account for an above-EU average share of the value we estimated (56%). A similar picture can also be seen in Italy and the Netherlands (61% and 62% of value realised by SMEs, respectively).

Figure 4.14 GVA generated by cloud services in 2023, by enterprise size and country



We also estimate the value of GVA generated by cloud services that originate specifically from firms that use only "basic" cloud services (as defined by Eurostat – including use of cloud for email, office software and file storage). This amounts to €13.2bn in the EU, or 11% of the total user-side economic value of cloud services in the EU.

"Non-basic only" cloud use therefore accounts for the remaining 89% of user-side value of cloud services in the EU, or €104.8bn. This category of cloud service usage consists of "intermediate" (related to use of software applications such as CRM, ERP or finance applications) and "sophisticated" (related to use of security software applications, hosting either for websites or application development) services.

iii. The economic value of ECBDFs to other regions

We also provide a high-level estimate of the user-side value at stake from ECBDFs that flow from the EU to non-European countries. This may be useful to inform ongoing and future policy, investment and trade negotiations at EU level. This value is not split by country of origin for the ECBDFs (e.g. separate value estimates are not provided for ECBDFs that flow from Belgium to Canada, or from France to Canada) but, instead, values are provided for ECBDFs that originate from the EU as a whole.

For example, to estimate the user value at stake from ECBDFs between the EU and the USA, we multiply: (i) the total user value of ECBDFs in the EU (€59bn) by (ii) the proportion of all ECBDFs that originate from the EU and flow to the USA (3.9%). The result, as shown in Table 4.4 below, is that around €2.3bn of user value of ECBDFs realised by enterprises in the EU are dependent on cloud flows of data between the EU and the USA.

This is a high-level assessment of value at stake rather than an estimate of the value of ECBDFs that flow from the EU to a given non-EU country A. This is because the calculation involves a necessary simplifying assumption: that the value of an exabyte of ECBDFs is the same regardless of the country of destination of that exabyte. This assumption is explained in further detail in Section 3 of the methodology note, and is necessary given that evidence to adjust the value-per-exabyte of specific individual country-to-country flows does not exist.

Our analysis indicates that, out of the total €59bn user-side value of ECBDFs in the EU in 2023, around €13bn is based on cloud data flows from EU Member States to non-EU countries, while the remaining €46bn is based on ECBDFs within the EU.

The “top” destinations of extra-EU ECBDFs within each region are:

- The USA and Canada in North America
- Israel and the UAE in the Middle East
- South Africa in Africa
- China and Japan in Asia

Ultimately, this “ranking” within each region is driven by the information obtained from publicly available sources on the location of main cloud data centres owned by the top cloud providers outside of Europe. This evidence is presented in Table 3.4 in Chapter 3.

Table 4.4 Value of ECBDFs from EU Member States to extra-EU regions and countries in 2023

Extra-EU region that ECBDFs flowed to	2023 ECBDFs value (€bn)	2023 ECBDF volume that flowed from EU (PB/year)
USA	1.1	552
Canada	1.1	552
Total America	**2.2**	**1,103**
Turkey	0.11	58
Israel	1.0	530
UAE	0.92	466
Bahrain	0.49	249
Qatar	0.50	252
Saudi Arabia	0.60	304
Total Middle East	**3.7**	**1,861**
Egypt	0.0	9
South Africa	1.6	821
Total Africa	**1.6**	**830**

China	0.43	220
Japan	0.48	242
India	0.41	209
Indonesia	0.21	106
Taiwan	0.04	20
South Korea	0.41	209
Malaysia	0.01	3
Thailand	0.02	9
Singapore	0.51	258
Total Asia	**2.5**	**1,276**
United Kingdom	**0.54**	276
EFTA countries	**2.7**	1390
Grand Total	**13.2**	**6,735**

iv. Forecast economic value of ECBDFs to cloud users

This chapter reports our estimates of the future demand-side value of ECBDFs in Europe.

These estimates use our projections of future cloud uptake and GVA by sector and country until 2035. We hold the DFCI, the third key drivers of our estimates of ECBDFs, constant. This is because there is insufficient data to assess the recent growth of DFCI indicators in order to build forecasts for values of DFCI indicators in future years. In particular, the majority of the DFCI indicators (as of the publication date of the report) only have data for a single year post Covid. Future applications of our framework will be able to improve on our estimates by producing DFCI forecasts as historical data becomes available. Table 4.5 below presents our estimates for the user-side value of ECBDFs[80] by country in 2024, 2025, 2030 and 2035. **Across the EU, the value of ECBDFs to users is forecast to increase to** €239bn by 2035 – an increase of **approximately 3.6 times compared to the 2023 value.** This average growth is primarily the result of increasing cloud uptake over time (which we expect to be 50% higher in 2035 compared to 2023) and overall economic growth in Europe leading to increased GVA (expected to be 60% higher in 2035 compared to 2023). The growth rates for both EFTA and the UK are lower than for the EU: in 2035 the user-side value of ECBDFs is expected to be €39bn and €20bn respectively (3.0 and 2.3 times the 2023 value compared to the EU ratio of 3.6).

Within the EU, Germany, Italy, Netherlands, Ireland and France are expected to remain among the top countries in terms of the value of ECBDFs generated, although Poland is expected to overtake France in 2035. On the other hand, Bulgaria, Latvia, Romania, Cyprus and Estonia are expected to remain the five countries that generate the lowest value of ECBDFs, again primarily due to the size of their economies.

The forecast value of ECBDFs, and the drivers of changes in value over time, differ across countries. We forecast Eastern European and Baltic countries to deliver the fastest percentage growth rates in the value of ECBDFs, with Latvia, Lithuania, Czechia and Hungary all forecast to generate ECBDF value in 2035 that is around eight to ten times the value in 2023. This result is largely due to very high growth rates in GVA for these countries, with many of their

80 Unlike in previous sections on current value, we do not present results by firm size and category of cloud service used (basic versus intermediate and sophisticated). This is in part due to data availability, as the time series of data on the uptake of different cloud services is not consistent over time with a break in series in 2021.

sectors forecast to grow at an annual rate of 10%, if prior trends are to continue.[81] Sweden, Finland, Norway and the UK have the slowest forecast growth, with the value of ECBDFs forecast to reach approximately twice its 2023 value in 2035. The relatively slower growth rate for these countries is due to a slower projected increase in cloud uptake, due to their higher starting level of cloud uptake. The UK's slower growth rate is also due to its relatively slow recent GVA growth.

Table 4.5 Forecast value of ECBDFs to users, by country (€bn)

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	20.5	24.9	51.1	85.1	599.5
Italy	8.4	9.4	14.6	20.0	169.2
Netherlands	6.6	7.6	13.7	22.0	162.1
Ireland	5.1	5.8	10.7	18.2	128.4
France	4.2	4.7	7.6	11.8	90.2
Sweden	5.3	5.7	7.3	8.9	85.7
Poland	2.7	3.2	6.9	12.8	83.5
Belgium	2.7	3.1	6.1	10.8	73.4
Austria	2.1	2.6	5.7	9.5	66.3
Spain	2.6	3.0	5.2	8.8	63.0
Finland	3.1	3.3	4.4	5.7	52.3
Denmark	2.2	2.4	3.6	5.0	42.5
Czechia	0.9	1.2	2.9	6.0	35.6
Portugal	0.7	0.8	1.7	3.2	20.8
Hungary	0.4	0.5	1.3	2.6	15.7
Croatia	0.2	0.3	0.6	1.2	7.4
Slovakia	0.2	0.2	0.5	1.0	6.2
Lithuania	0.2	0.2	0.5	1.1	6.2
Luxembourg	0.2	0.3	0.5	0.9	6.1
Slovenia	0.2	0.2	0.5	0.9	5.7
Malta	0.2	0.2	0.4	0.7	4.6
Greece	0.2	0.2	0.4	0.6	4.6
Estonia	0.1	0.1	0.3	0.6	4.0
Cyprus	0.1	0.2	0.3	0.6	4.0
Romania	0.1	0.1	0.2	0.5	3.0
Latvia	0.1	0.1	0.2	0.5	2.9
Bulgaria	0.0	0.0	0.1	0.2	1.0
United Kingdom	19.1	21.0	30.0	38.8	348.5
Switzerland	4.1	4.7	8.2	13.0	96.9
Norway	3.0	3.2	4.5	5.9	52.8
Iceland	0.2	0.3	0.5	0.7	5.4
Liechtenstein	0.1	0.1	0.1	0.2	1.5
EU	**69.2**	**80.3**	**147.2**	**239.3**	**1743.8**

81 Based on recent trends, seven of Hungary's 17 sectors are forecast to grow at least at 10% per annum, with seven Czechia sectors, six Lithuania sectors and three of Latvia's sectors also forecast to grow at 10% or more per annum.

EFTA	7.4	8.2	13.3	19.8	156.5
Total	95.7	109.6	190.5	297.8	2248.8
Average EU	2.6	3.0	5.5	8.9	64.6

We also forecast the value of ECBDFs for SME and large enterprise changes over time. Assuming that the ratio of SME and large enterprise ECBDFs value is constant, our forecasts imply that the value of ECBDFs to large cloud-using enterprises in the EU will be €74.0bn in 2030 and €120.3bn in 2035, and that the value to SMEs will be €73.2bn in 2030 and €119.0bn in 2035.

Tables 4.6 to 4.9 present our estimates for the value of ECBDFs, **by sector over time**, separately for the EU, EFTA and the UK, and the total across EU, the UK and EFTA.

The growth rates of the value of ECBDFs to users across the EU also vary across sector, but to a lesser extent than across countries. This is due to forecast economic growth (GVA) varying more between countries than between sectors.

Table 4.6 Forecast value of ECBDFs to cloud-using enterprises in the EU, by sector (NACE C to S, €bn)

NACE	Sector	2024	2025	2030	2035
C	Manufacturing	14.0	16.6	31.4	49.5
G	Wholesale and retail trade	9.5	11.3	22.1	36.4
J	Information and communication	8.8	9.6	14.4	21.2
L	Real estate activities	7.2	8.1	13.5	20.8
M	Professional, scientific and technical	5.4	6.0	9.5	14.1
Q	Human health and social work activities	3.8	4.5	8.9	15.1
K	Financial and insurance activities	4.8	5.2	7.2	9.6
N	Administrative and support services	2.3	2.8	6.1	11.0
O	Public administration and defence	2.8	3.3	6.5	10.8
F	Construction	2.0	2.4	5.4	10.8
H	Transportation and storage	2.1	2.6	5.9	11.4
P	Education	2.3	2.8	5.4	9.1
D	Electricity, gas, steam and air conditioning	1.5	1.8	3.6	6.6
I	Accommodation and food service	0.8	1.0	2.4	4.7
S	Other service activities	0.8	0.9	1.8	2.9
E	Water supply; sewerage and waste	0.6	0.8	1.7	3.0
R	Arts, entertainment and recreation	0.5	0.7	1.3	2.3
	Total EU	**69.2**	**80.3**	**147.2**	**239.3**

Accommodation & food service has the highest forecast growth in user-side ECBDF value, with a forecast value in 2035 equal to 8.2 times its value in 2023. This is due to a faster annual growth rate in GVA than other sectors (c. 6% average). Financial services and information & communication have the lowest forecast growth rate in ECBDFs. In the case of financial services, this is due to a lower GVA growth rate, whereas in the case of information & communication it is due to a slower increase in cloud uptake, related to higher existing cloud uptake in 2023 for the sector.[82]

Again the picture for the UK is different to the EU, but the EFTA countries are more similar. As above, the UK's slower growth across its sectors is a combination of slower GVA growth and lower growth in cloud uptake. Financial services particularly stands out, with a forecast value of ECBDFs in 2035 that is less than its current 2023 value.

Table 4.7 Forecast value of ECBDFs to cloud-using enterprises in the UK, by sector (NACE C to S, €bn)

NACE	Sector	2024	2025	2030	2035
C	Manufacturing	2.3	2.5	3.2	3.7
G	Wholesale and retail trade	2.3	2.6	4.3	6.0
J	Information and communication	2.9	2.9	3.3	3.8
L	Real estate activities	2.0	2.3	3.3	4.1
M	Professional, scientific and technical	2.0	2.1	2.3	2.6
Q	Human health and social work activities	1.1	1.3	2.3	3.3
K	Financial and insurance activities	1.8	1.8	1.8	1.7
N	Administrative and support services	0.7	0.8	1.5	2.2
O	Public administration and defence	0.7	0.8	1.4	2.1
F	Construction	0.7	0.8	1.3	2.0
H	Transportation and storage	0.6	0.7	1.1	1.6
P	Education	0.8	0.9	1.5	2.0
D	Electricity, gas, steam and air conditioning	0.3	0.3	0.5	0.6
I	Accommodation and food service	0.4	0.5	0.8	1.1
S	Other service activities	0.2	0.3	0.5	0.7
E	Water supply; sewerage and waste	0.2	0.2	0.4	0.6
R	Arts, entertainment and recreation	0.2	0.2	0.4	0.6
	Total UK	**19.1**	**21.0**	**30.0**	**38.8**

[82] In 2023, 79.0% of EU enterprises paid for cloud services used over the internet, compared to 45.2% of EU enterprises across all sectors.

Table 4.8 Forecast value of ECBDFs to cloud-using enteprises in EFTA, by sector (NACE C to S, €bn)

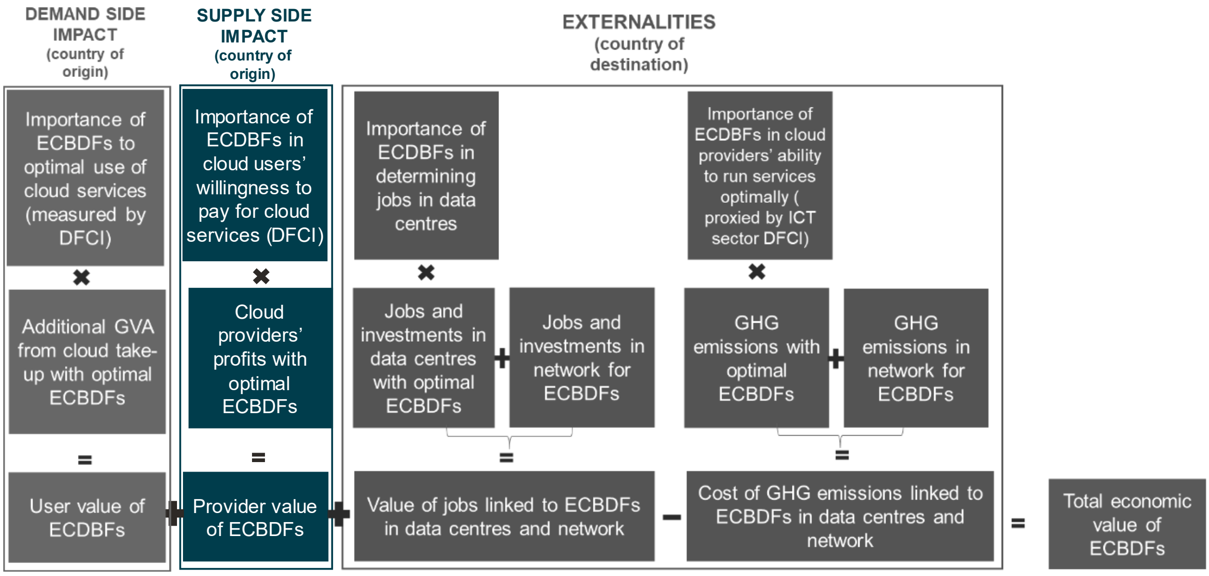
NACE	Sector	2024	2025	2030	2035
C	Manufacturing	1.0	1.2	2.2	3.6
G	Wholesale and retail trade	1.0	1.2	1.9	2.9
J	Information and communication	0.8	0.8	1.0	1.3
L	Real estate activities	0.6	0.6	1.0	1.5
M	Professional, scientific and technical	0.7	0.8	1.3	1.8
Q	Human health and social work activities	0.6	0.7	1.2	1.9
K	Financial and insurance activities	0.8	0.9	1.2	1.5
N	Administrative and support services	0.2	0.2	0.4	0.7
O	Public administration and defence	0.4	0.5	0.8	1.3
F	Construction	0.3	0.3	0.5	0.8
H	Transportation and storage	0.1	0.2	0.3	0.6
P	Education	0.2	0.2	0.3	0.4
D	Electricity, gas, steam and air conditioning	0.3	0.3	0.5	0.9
I	Accommodation and food service	0.04	0.05	0.1	0.2
S	Other service activities	0.1	0.1	0.1	0.2
E	Water supply; sewerage and waste	0.04	0.05	0.1	0.1
R	Arts, entertainment and recreation	0.1	0.1	0.1	0.1
	Total EFTA	**7.4**	**8.2**	**13.3**	**19.8**

Table 4.9 Forecast value of ECBDFs to cloud-using enterprises in Europe (EU + EFTA + UK), by sector (NACE C to S, €bn)

NACE	Sector	2024	2025	2030	2035
C	Manufacturing	17.3	20.3	36.8	56.8
G	Wholesale and retail trade	12.8	15.1	28.3	45.2
J	Information and communication	12.4	13.3	18.7	26.4
L	Real estate activities	9.8	11.0	17.8	26.4
M	Professional, scientific and technical	8.2	8.9	13.1	18.6
Q	Human health and social work activities	5.5	6.5	12.4	20.3
K	Financial and insurance activities	7.4	7.9	10.3	12.8
N	Administrative and support services	3.2	3.8	7.9	13.9
O	Public administration and defence	3.9	4.7	8.8	14.1
F	Construction	2.9	3.5	7.3	13.6
H	Transportation and storage	2.9	3.5	7.4	13.5
P	Education	3.3	3.9	7.3	11.5
D	Electricity, gas, steam and air conditioning	2.0	2.4	4.6	8.1
I	Accommodation and food service	1.2	1.5	3.3	6.1
S	Other service activities	1.1	1.3	2.4	3.9
E	Water supply; sewerage and waste	0.9	1.0	2.2	3.7
R	Arts, entertainment and recreation	0.8	0.9	1.8	3.0
	Total Europe	**95.7**	**109.6**	**190.5**	**297.8**

d. The economic value of ECBDFs to cloud providers (supply-side impacts)

i. Current value of ECBDFs to cloud providers



As discussed in Chapter 2, from a microeconomic perspective, the economic value of cloud services to cloud providers can be approximated as the profit generated by the provision of such services.[83]

Estimating the economic value of cloud services to cloud providers is one of the intermediate steps we take in this study but it is not the ultimate objective, which is to estimate the value of ECBDFs.

In order to achieve this objective, in line with the methodology adopted on the user side and presented in the previous sections, we attempt to isolate the proportion of provider profits that can be attributed to ECBDFs specifically using the DFCI. In order to estimate provider profits, we multiply the estimated revenues made by providers in each country under analysis by the average profit margin made by major cloud providers. Subsequently, in order to isolate the proportion of these profits attributable to ECBDFs, we multiply these profits by the average DFCI calculated for the country of origin of the ECBDFs under analysis.

The revenues (current and future) of the cloud sector in each European country are obtained from publicly available market research reports,[84] while average margins are calculated based

83 As discussed in chapter 1, we look at profits and not at revenues because, from a supply-side perspective, revenues represent a transfer of resources from the consumer (i.e. the enterprise using the cloud service) to the producer (i.e. the provider selling the same service). Conversely, profits represent genuine added value to the economy from the perspective of the provider. Indeed, as discussed in the introduction to this chapter, microeconomic theory defines producers' surplus as the profits made by producers in a given market.

84 https://www.gminsights.com/industry-analysis/europe-cloud-computing-market.https://www.gminsights.com/industry-analysis/europe-cloud-computing-market. This source provides for free, upon request via email, estimated Europe Cloud Computing Market Size for 2021 for the following geographic zones: UK, Germany, Italy, Spain, Netherlands, Switzerland, Nordics and Rest of Europe.

on data obtained from the annual reports of the main cloud providers included in this study (AWS, Google, Azure, IBM and Oracle).[85]

As discussed in Chapter 1, the reason why the DFCI is also used on the supply side of our framework is because the value that providers can extract from ECBDFs is directly linked to the value that their customers can extract from these flows. Indeed, in a counterfactual scenario where ECBDFs were artificially restricted, enterprises that use cloud services would be able to add less value to their activities and to the economy and therefore would be willing to pay less for cloud services, which, in turn, would reduce their profits. The magnitude of this decline (in percentage terms) would be expected to be similar to the decline in GVA experienced on the demand side (also in percentage terms). For example, if the DFCI in a given country and sector (e.g. Italian construction sector) is 50%, this means that half of the GVA that enterprises which use cloud services in that sector and country extracted from cloud services are attributable to ECBDFs (let us say €50m out of €100m of GVA). On the supply side, it means that half of the profits made by providers that sell cloud services to that sector in that country are attributable to ECBDFs (let us say €5m out of €10m of profits).

The following tables and charts show the results of these calculations for each country under analysis. As mentioned above, the profits of cloud providers are obtained from publicly available sources that provide estimates broken down by country but not by cloud provider or by service type. The DFCI used to estimate the proportion of these profits that is attributable to ECBDFs is different in each country and is the same used to estimate user-side value.

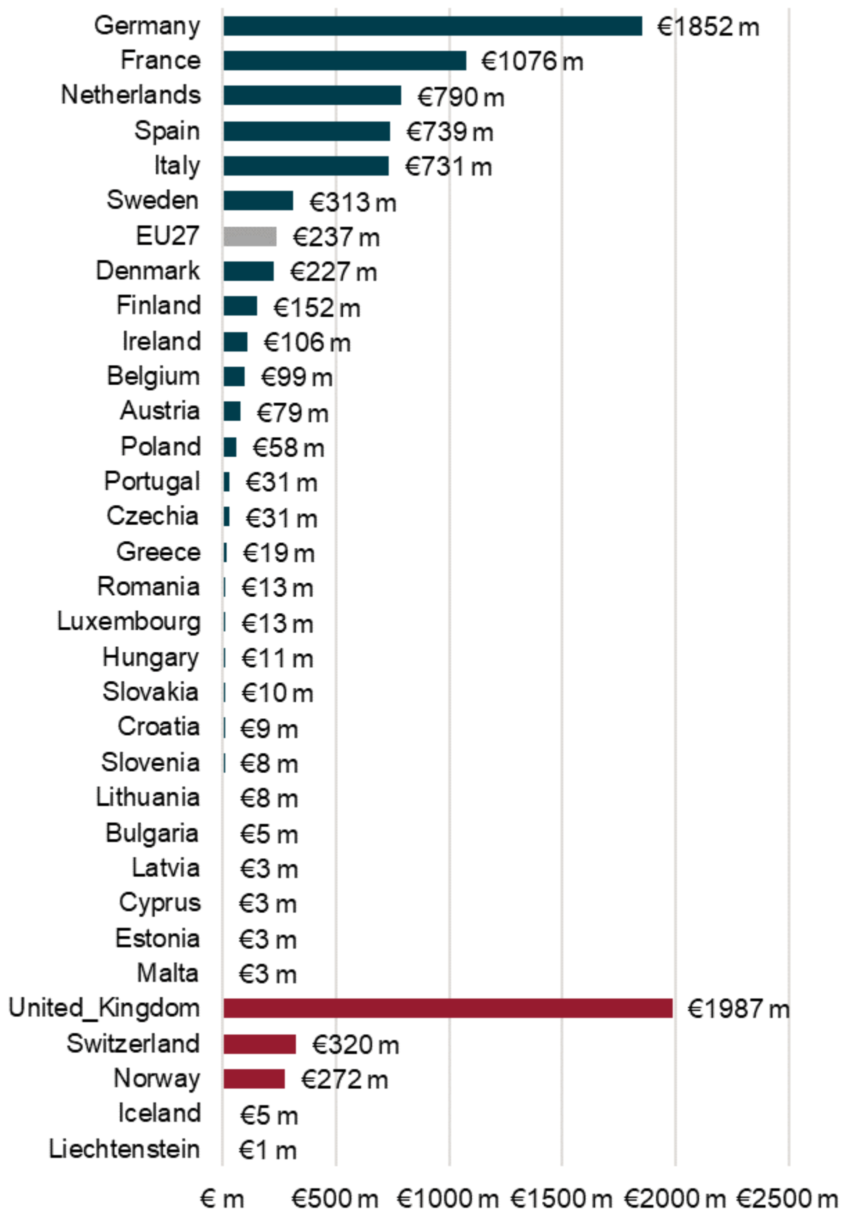
We estimate that **the supply-side value of ECBDFs in 2023 was €6.4bn for the EU**, **€600m for EFTA countries**, **and just under €2bn for the UK**. Therefore, **the total supply-side value of ECBDFs in 2023 in Europe was just under €9bn**.

As shown in Figure 4.15 below, in terms of supply-side value of ECBDFs, the bottom five countries in which providers extract less value are Liechtenstein, Cyprus, Malta, Estonia and Latvia, which collectively account for less than €15m of supply-side value.

On the other end of the spectrum, the top five are Spain, Netherlands, France, Germany and the UK, where the combined estimated supply-side value of ECBDFs exceeded €6bn in 2023. This ranking is mostly driven by the smaller/larger size of these economies (and therefore by the large size of the market that can be served by cloud providers and from which they can extract profits).

85 Further detail on this calculation is provided in Section 3 of the methodological note.

Figure 4.15 Value of ECBDFs from a provider perspective (€m), 2023



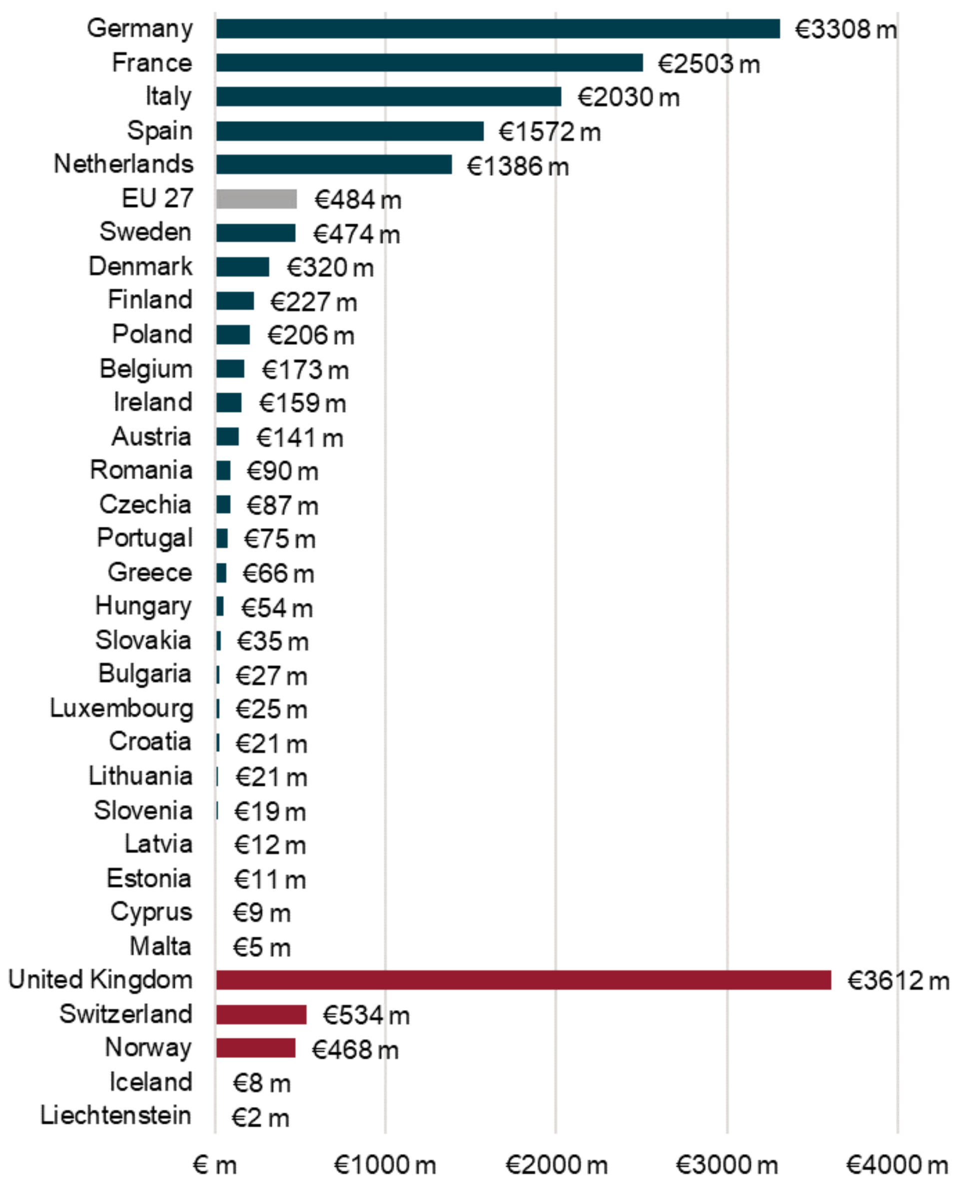
In some instances, however, the relative ranking of countries in terms of supply-side value is different from the relative ranking in terms of profits. These changes are driven by the DFCI, which is multiplied by the profits estimated in each country to calculate the provider-side value of ECBDFs. For example, cloud providers are estimated to make higher profits in Italy than in Spain (as shown in Figure 4.16 below) while the value of ECBDFs from a provider perspective is slightly higher in Spain than in Italy (as shown in Figure 4.15 above). This is due to the fact that the DFCI estimated for Spain is materially higher than the one estimated for Italy (47% vs 36%). In other words, the DFCI indicates that cloud providers are more reliant on ECBDFs to make profits in Spain compared to Italy. This example shows the relevance of both components of the equation used to estimate the supply-side value of ECBDFs: provider profits and the proportion of these profits that can be attributed to ECBDFs using the DFCI. It also highlights the main contribution of this report to the economic literature on cloud services and data flows more generally. This contribution is the DFCI: a composite indicator which aims to isolate the economic value of ECBDFs from the wider value of cloud services.

Across the EU as a whole, we estimate that in 2023 cloud providers made **€13bn profits**. In EFTA countries, this was **€1bn**, and in the UK it was **€3.6bn**. Therefore, across Europe as a whole, cloud providers made around **€17.7bn profits in 2023.**

For the sake of clarity, these estimates are derived by multiplying the same average profit margin (29%) by the estimated cloud revenues of the major cloud providers that operate in each European geography. In this context, it is important to note that this average profit margin is a crude measure extracted from publicly available information and might not reflect the actual market conditions in which providers operate in each country and the complexities and the subtleties that characterise the annual accounts of such large multinational and multiproduct companies. Future research might want to investigate this aspect further and potentially produce country-specific estimates of profit margins

As shown in Figure 4.16 overleaf, in 2023, cloud providers are estimated to make material profits in large countries like the UK (€3.6bn) and Germany (€3.3bn). This is mainly due to the size of these markets, which have more enterprises and therefore are expected to represent a larger source of revenue for major cloud providers.

Figure 4.16 Estimated profits of cloud providers (in €m), 2023



Overall, our analysis suggests that, in the EU, cloud providers are estimated to make **€484m** profits per country, on average, as of 2023 (as shown in the grey bar in Figure 4.16). On average, **€237m** of these are estimated to be attributable to ECBDFs, as shown in the grey bar in Figure 4.15.

ii. Future value of ECBDFs to cloud providers

The supply-side value of ECBDFs in the EU is estimated to increase by a factor of 5.6 between 2024 and 2035 from €7.8bn to €44bn. For context, €44bn is higher than the current GDP of Latvia.[86]

Cumulatively, between 2024 and 2035, we estimate that the total value realised by cloud providers from EU ECBDFs will be around €328bn. Table 4.10 below provides equivalent figures for EFTA, the UK and Europe as a whole.

In terms of future forecasts of supply-side value of ECBDFs, as shown in the table below, the bottom five countries remain Liechtenstein, Malta, Estonia, Cyprus and Latvia, while the top five remain Spain, Netherlands, France, Germany and the UK. The relative rankings of different countries in future years do not change over time, as the DFCI calculated for each country is assumed to remain constant over time, while the overall value varies in relation to the size of each country's economy.

Table 4.10 Value of ECBDFs from a provider perspective per country (in €m – 2024-2035)

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	€2,278 m	€2,780 m	€6,631 m	€12,762 m	€94,505 m
France	€1,324 m	€1,615 m	€3,853 m	€7,417 m	€54,919 m
Netherlands	€972 m	€1,186 m	€2,828 m	€5,443 m	€40,307 m
Spain	€909 m	€1,109 m	€2,644 m	€5,090 m	€37,687 m
Italy	€899 m	€1,096 m	€2,616 m	€5,034 m	€37,277 m
Sweden	€385 m	€469 m	€1,119 m	€2,154 m	€15,949 m
Denmark	€279 m	€341 m	€812 m	€1,564 m	€11,578 m
Finland	€187 m	€228 m	€544 m	€1,048 m	€7,760 m
Ireland	€131 m	€159 m	€380 m	€732 m	€5,420 m
Belgium	€122 m	€148 m	€354 m	€681 m	€5,041 m
Austria	€97 m	€119 m	€283 m	€545 m	€4,035 m
Poland	€71 m	€87 m	€207 m	€398 m	€2,946 m
Portugal	€38 m	€46 m	€111 m	€213 m	€1,579 m
Czechia	€38 m	€46 m	€109 m	€210 m	€1,557 m
Greece	€23 m	€29 m	€68 m	€131 m	€971 m
Romania	€16 m	€19 m	€45 m	€87 m	€645 m
Luxembourg	€15 m	€19 m	€45 m	€87 m	€641 m
Hungary	€14 m	€17 m	€40 m	€78 m	€574 m
Slovakia	€12 m	€15 m	€35 m	€67 m	€494 m
Croatia	€11 m	€13 m	€31 m	€60 m	€445 m
Slovenia	€10 m	€12 m	€29 m	€55 m	€408 m

86 Just under €39bn as of 2022, the latest year for which GDP data is available from Eurostat.

Lithuania	€10 m	€12 m	€28 m	€54 m	€398 m
Bulgaria	€6 m	€7 m	€17 m	€33 m	€245 m
Latvia	€4 m	€5 m	€12 m	€24 m	€176 m
Cyprus	€4 m	€5 m	€11 m	€21 m	€157 m
Estonia	€4 m	€4 m	€11 m	€20 m	€151 m
Malta	€4 m	€4 m	€10 m	€20 m	€149 m
United Kingdom	€2,443 m	€2,981 m	€7,111 m	€13,687 m	€101,350 m
Switzerland	€394 m	€481 m	€1,147 m	€2,207 m	€16,344 m
Norway	€334 m	€408 m	€972 m	€1,871 m	€13,856 m
Iceland	€7 m	€8 m	€19 m	€37 m	€277 m
Liechtenstein	€1 m	€2 m	€4 m	€8 m	€57 m
EU	**€7,860 m**	**€9,589 m**	**€22,875 m**	**€44,027 m**	**€326,016 m**
UK	€2,443 m	€2,981 m	€7,111 m	€13,687 m	€101,350 m
EFTA	€736 m	€898 m	€2,142 m	€4,123 m	€30,534 m
Total	€11,040 m	€13,468 m	€32,129 m	€61,837 m	€457,899 m
Average EU	€291 m	€355 m	€847 m	€1,631 m	€12,075 m

As shown in Table 4.11 below, average EU profits are expected to increase by the same factor of 5.6 from 2024 (€600mn) to 2035 (€3.3bn). This is mainly due to the estimated growth rate of the European cloud market (assumed to decline linearly from 25% per annum in 2022-23 to 12% per annum in 2035-36).

Table 4.11 Estimated cloud provider profits by country – 2024-2035

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	€4,069 m	€4,964 m	€11,841 m	€22,790 m	€143,461 m
France	€3,079 m	€3,757 m	€8,961 m	€17,248 m	€108,574 m
Italy	€2,496 m	€3,046 m	€7,265 m	€13,984 m	€88,025 m
Spain	€1,933 m	€2,359 m	€5,626 m	€10,829 m	€68,166 m
Netherlands	€1,705 m	€2,080 m	€4,962 m	€9,550 m	€60,114 m
Sweden	€583 m	€711 m	€1,696 m	€3,263 m	€20,543 m
Denmark	€393 m	€480 m	€1,144 m	€2,202 m	€13,863 m
Finland	€279 m	€341 m	€813 m	€1,564 m	€9,846 m
Poland	€254 m	€309 m	€738 m	€1,421 m	€8,943 m
Belgium	€213 m	€260 m	€621 m	€1,194 m	€7,519 m
Ireland	€195 m	€238 m	€568 m	€1,093 m	€6,877 m
Austria	€174 m	€212 m	€506 m	€973 m	€6,126 m
Romania	€111 m	€135 m	€323 m	€622 m	€3,915 m
Czechia	€107 m	€131 m	€312 m	€601 m	€3,781 m
Portugal	€93 m	€113 m	€270 m	€520 m	€3,274 m
Greece	€81 m	€98 m	€235 m	€452 m	€2,847 m
Hungary	€66 m	€80 m	€192 m	€369 m	€2,323 m
Slovakia	€43 m	€52 m	€124 m	€238 m	€1,501 m
Bulgaria	€33 m	€40 m	€96 m	€184 m	€1,157 m
Luxembourg	€30 m	€37 m	€88 m	€170 m	€1,069 m
Croatia	€26 m	€32 m	€76 m	€146 m	€922 m
Lithuania	€26 m	€32 m	€75 m	€145 m	€914 m
Slovenia	€23 m	€28 m	€67 m	€128 m	€807 m
Latvia	€15 m	€19 m	€44 m	€85 m	€535 m

Estonia	€14 m	€17 m	€41 m	€79 m	€495 m
Cyprus	€10 m	€13 m	€31 m	€59 m	€370 m
Malta	€7 m	€8 m	€19 m	€37 m	€231 m
United Kingdom	€4,443 m	€5,420 m	€12,930 m	€24,885 m	€156,650 m
Switzerland	€657 m	€801 m	€1,911 m	€3,679 m	€23,157 m
Norway	€576 m	€703 m	€1,676 m	€3,226 m	€20,309 m
Iceland	€10 m	€13 m	€30 m	€57 m	€362 m
Liechtenstein	€3 m	€3 m	€8 m	€14 m	€91 m
Total EU	**€16,058 m**	**€19,590 m**	**€46,733 m**	**€89,945 m**	**€566,197 m**
UK	€4,443 m	€5,420 m	€12,930 m	€24,885 m	€156,650 m
EFTA	€1,246 m	€1,520 m	€3,625 m	€6,977 m	€43,918 m
Total Europe	**€21,746 m**	**€26,530 m**	**€63,287 m**	**€121,808 m**	**€766,766 m**
Average EU	€595 m	€726 m	€1,731 m	€3,331 m	€20,970 m

The relative positioning of different countries in tables 4.10 and 4.11 above is also very similar. In most cases, the DFCI (which is used to estimate the proportion of providers' profits that is attributable to ECBDFs) is not sufficiently volatile to compensate for the volatility in the estimated profits of providers.

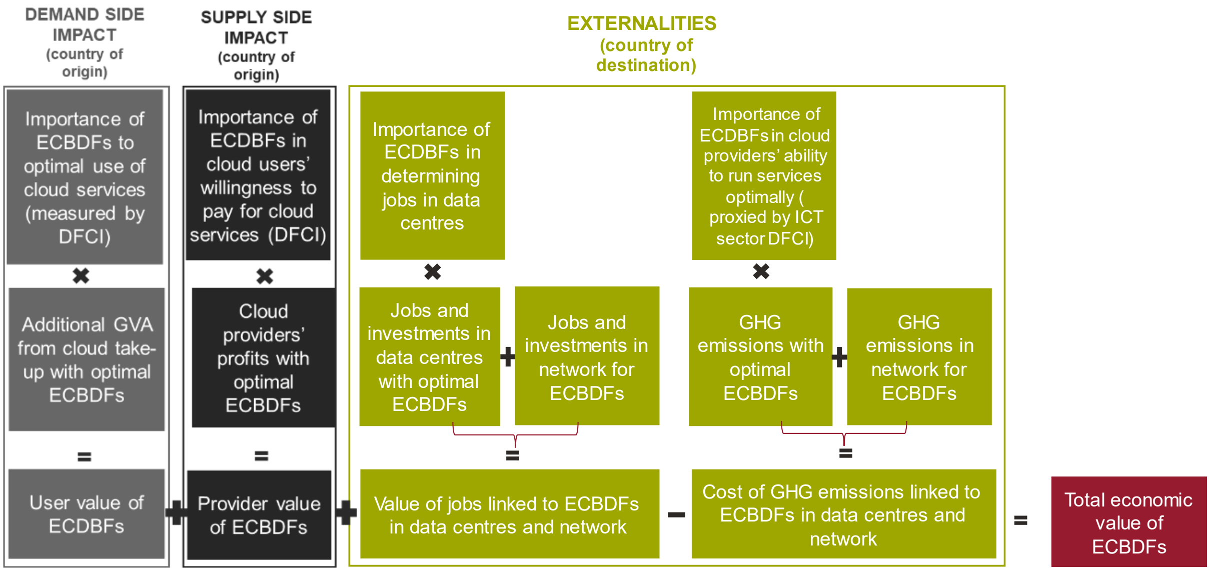
However, as discussed above, there are some countries where this is the case. For example, the Netherlands moves from sixth to fourth place due to a particularly high DFCI (high criticality of ECBDFs to cloud service users) compared to other countries with higher cloud provider profits like Spain and Italy.

As data on providers' revenues (from which profits can be estimated) is not available at a more granular level than country level (e.g. sector, cloud service type), this section presents only estimates at a country level, which explains why this section is relatively more succinct compared to the demand-side one.

In conclusion, as discussed in more detail at the end of the chapter, the proportion of economic value driven by the supply side of the market is estimated to be material but lower than the proportion represented by the demand side of the market: total demand-side value in 2023 is €82bn, while the supply-side is estimated to be €9bn.

From a policy perspective, these results indicate that there could be significant value in policy interventions that are aimed at stimulating the demand/uptake for cloud services – as even a small increase in demand-side value (say 5%) could generate a large amount of economic value (€4bn).

e. The economic value of ECBDFs to the wider economy (externalities)



In the previous sections, we estimated the value of ECBDFs to the cloud-using enterprises from where (origin) these flows originated (user-side or demand-side value), and to the cloud providers which provide cloud services to these enterprises: the destination of the ECBDFs (provider-side or supply-side value).

In this section, we explore how ECBDFs can also have a wider impact for society/economy via their impacts on the environment and jobs, through:

- **Greenhouse gas emissions (GHG)**, and
- **The creation of direct, indirect and induced jobs**.

We collectively label both of these impacts as "externalities". These impacts are attributed to the country of destination of the ECBDFs, because they arise through two channels:

- The consumption of energy and the jobs required to ensure that ECBDFs flow through the connecting infrastructure in the country of destination (i.e. through cables, exchange stations, servers and switches); and
- The consumption of energy and the jobs required to ensure that ECBDFs are received in the cloud data centres in the country of destination, and that the data is stored, maintained and processed in those data centres.

In both cases, we include direct jobs (e.g. workers employed directly in maintaining exchange stations and cloud data centres) as well as indirect jobs (e.g. workers employed in the local economy to provide goods and services to cloud data centres) and induced jobs (e.g. workers employed in the local economy to provide goods and services consumed by the individuals who work in cloud data centres).

In this context, the definition of country of destination includes: ECBDFs that flow from another country to the country under analysis as well as ECBDFs that flow within the country under analysis (i.e. that originate from an enterprise located in that country and flow to a cloud facility located within the same country). For example, as outlined in Chapter 2, we estimate that, in 2023, Spain generated 2,465 PB of ECBDFs and that 1,356 PB of these flowed to cloud facilities located in Spain and the remainder of these flowed to cloud facilities located in other countries. In addition, we estimate that 255 PB of ECBDFs flowed from other European countries to cloud facilities located in Spain. In this specific example, the volume of ECBDFs relevant to estimate externalities in Spain is 1,611 PB (1356 PB + 255 PB).

As for our approach to enterprise and provider ECBDF value, we attempt to estimate the wider economic value that can be attributed to ECBDFs from the overall wider economic value of cloud services.

With regard to the first mechanism (ECBDFs that flow through the connecting infrastructures), we assume that **all the emissions and the jobs generated by ECBDFs that flow within and to a given country in the network are attributable to ECBDFs**.

As for the second mechanism (ECBDFs stored in data centres), we assume that **only a proportion of the jobs and the emissions generated by ECBDFs in the data centres of the country of destination are attributable to ECBDFs** because some of the jobs and the emissions generated by these data centres are attributable to cloud services generally and not to ECBDFs specifically.

Chapter 2 of this report and the methodological note (Section 3.3) provide more details on how these calculations and estimates are performed.

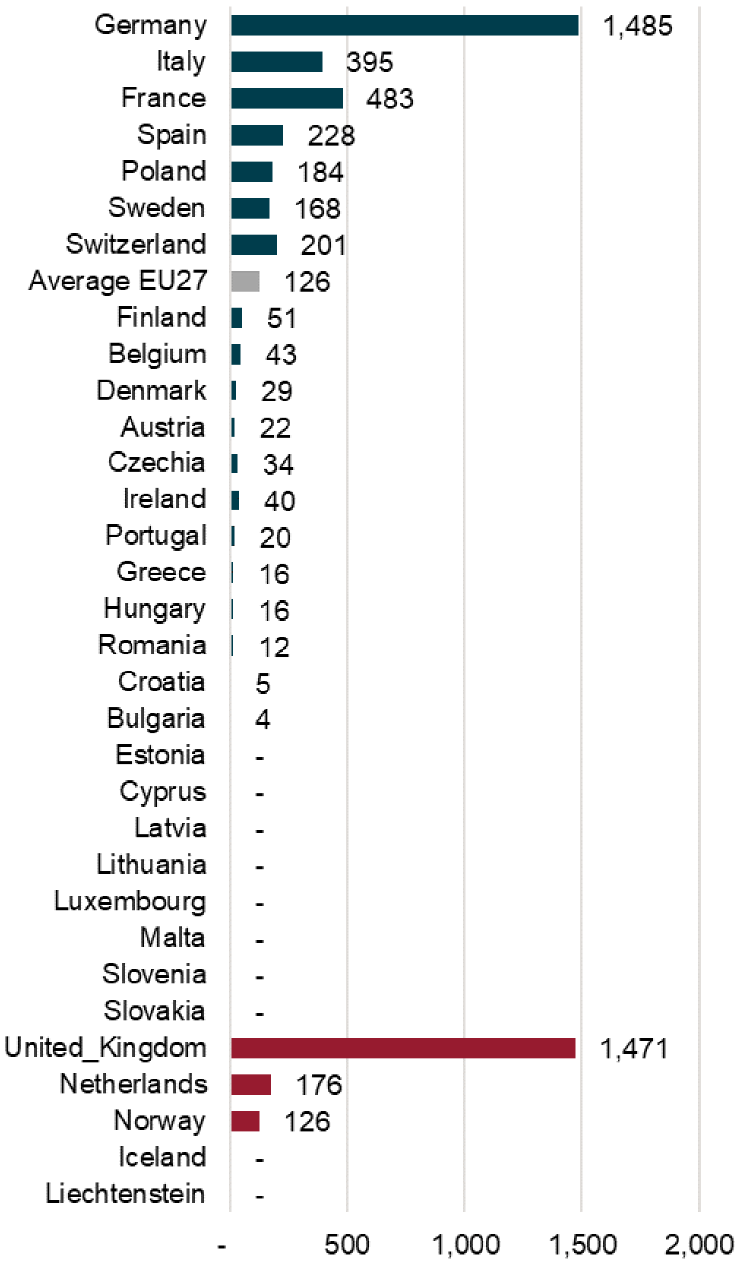
i. Direct, indirect and induced jobs

We estimate that, in 2023, ECBDFs generated 3,410 jobs in the EU, including both jobs linked to the connecting infrastructure and jobs linked to cloud data centres. For EFTA countries, this was 330 jobs; for the UK, it was 1,470 jobs; for Europe as a whole, it was 5,210 jobs.

In 2023, the vast majority of jobs are assumed to have been generated by ECBDFs in data centres (99%) and only 1% in the connecting infrastructures. This is because the latter is substantially less labour intensive (estimated to generate 3.4 direct jobs per Gigabit per second (Gbps), compared to nine direct jobs per EX in data centres), and it also has a smaller impact on the local economy in terms of indirect and induced jobs (likely due to the fact that the direct jobs of data centres are concentrated in one place, while in the case of cables they are geographically dispersed). This also means that the overall split between direct jobs and indirect/induced jobs (across both connecting infrastructure and in data centres) is approximately 1:24.

Further details on our calculations are provided in Section 3 of the methodological note.

Figure 4.17 Jobs attributable to ECBDFs by country, 2023 (full-time equivalents (FTEs), direct, indirect and induced jobs)



As shown in Figure 4.17 above, the top five countries in terms of the number of total jobs (direct, indirect and induced) generated by ECBDFs in 2023 are Germany, France, the UK, Spain and Italy. On the other end of the spectrum, all the countries that are not expected to have a data centre operated by one of the main cloud providers included in this analysis do not experience any added economic value in terms of local economic impacts and jobs. These countries are Estonia, Cyprus, Latvia, Lithuania, Luxembourg, Malta, Slovenia, Slovakia, Iceland and Liechtenstein.

Differences between the estimated jobs created by ECBDFs in each country are mostly driven by the volume of ECBDFs estimated to be processed in each country. This means that countries that host data centres operated by multiple providers (which are described in Chapter 3 of this report) are expected to process more ECBDFs than countries that host only one or two data centres.

In addition, these differences are also caused by differences in average productivity between countries, with high-productivity countries assumed to require fewer FTEs than less productive countries to process the same EX of cloud data.[87]

These differences between countries where ECBDFs generate more jobs and those where they generate none or fewer are expected to persist in the future, as shown by the forecasts reported below.

Table 4.12 Jobs associated with ECBDFs in each country (full-time equivalents, (FTEs), direct, indirect and induced)

Country	2024	2025	2030	2035
Germany	2,188	3,148	22,166	169,695
France	660	1,104	9,765	92,190
Italy	650	851	6,217	55,194
Spain	393	677	5,866	53,588
Netherlands	327	569	4,329	30,547
Sweden	271	440	3,649	33,618
Denmark	258	302	2,197	21,651
Finland	98	189	2,385	27,204
Poland	82	154	1,453	11,553
Belgium	63	128	1,086	8,646
Ireland	62	148	1,770	20,114
Austria	58	97	1,014	7,458
Romania	53	69	277	1,169
Czechia	35	59	730	6,660
Portugal	30	57	581	5,460
Greece	27	44	463	3,545
Hungary	18	28	230	1,421
Slovakia	9	14	165	1,435
Bulgaria	6	11	129	1,171
Luxembourg	-	-	-	-
Croatia	-	-	-	-
Lithuania	-	-	-	-
Slovenia	-	-	-	-
Latvia	-	-	-	-
Estonia	-	-	-	-
Cyprus	-	-	-	-
Malta	-	-	-	-
United Kingdom	2,148	3,123	20,319	140,273
Switzerland	271	412	3,507	28,408
Norway	154	168	1,143	9,699
Iceland	-	-	-	-
Liechtenstein	-	-	-	-
Total EU	**5,288**	**8,088**	**64,472**	**552,321**

[87] Further detail on this data and calculations is provided in section 3 of the methodological note.

UK	2,148	3,123	20,319	140,273
Total EFTA	425	580	4,650	38,107
Total Europe (EU + EFTA + UK)	**7,861**	**11,790**	**89,441**	**730,702**
Average EU	196	304	2,436	20,707

As shown in Table 4.12 above, ECBDFs are expected to generate over **500,000 FTE jobs across the EU by the end of the period under analysis in this report (2035)**. This is mainly due to the fact that ECBDFs are expected to increase by a factor of nearly 200 by 2035, as discussed in more detail in Chapter 2. As a result, a significantly larger volume of ECBDFs is expected to generate a significantly larger amount of positive job creation externalities. Please note that in this case we do not report a cumulative number of jobs created between 2024 and 2035. This is because some of the jobs created in one year (e.g. 2024) would still be in existence in the following year (2025) and therefore summing across two years would involve double-counting.

In order to assign a monetary value to each job estimated in the table above, we use the average value added to the economy by a worker in the ICT sector (which is the sector where workers in communications and data centres would be employed). For example, if ECBDFs that flow to a given country generate ten jobs and the average GVA of an ICT worker in that country is €100,000, then the monetary value of those jobs is €1m).[88]

Our results are shown in Figure 4.18 below. We estimate that in 2023, the economic value of jobs generated through ECBDFs was €315m in total across the EU, €36m in EFTA, €145m in the UK, and €500m in total in Europe. As mentioned above, the vast majority of this value is assumed to be generated in data centres (99%) and only 1% in the connecting infrastructure.

The ranking of countries according to the value of jobs associated with ECBDFs is similar to the ranking seen earlier according to the number of these jobs. However, some countries like Sweden have relatively higher positions in the ranking of the value of jobs compared to the ranking of the number of jobs. This is because of the higher labour productivity in these countries compared to others in Europe, which is reflected in a higher average GVA generated by an ICT worker in these countries compared to others in Europe.

Conversely, the countries that do not host cloud data centres (like Cyprus, Estonia, Malta and Luxembourg) and therefore see only an outflow of ECBDFs are not expected to benefit from this job creation. This is why some countries do not show an economic value associated with job creation stemming from ECBDFs in the tables below. In other words, as the externalities are assumed to be generated in the country of destination of ECBDFs, if a country does not host a data centre and therefore is not a destination of any flow (and none of the ECBDFs it generates flow to cloud facilities located within the same country), there will be no local economic externalities, either in terms of energy consumption or in terms of job creation, generated by ECBDFs in that country.

88 As explained in more detail in Section 3 of the methodological note, the economic value of each direct, indirect or induced job is estimated using the average GVA per worker in the ICT published by Eurostat for each European country. Eurostat source: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=ICT_sector_-_value_added,_employment_and_R%26D#Apparent_labour_productivity

Figure 4.18 Economic value of jobs generated by ECBDFs in each country, 2023 (€m)

As shown in Table 4.13 below, the average (in the EU) economic value of these jobs associated with ECBDFs (i.e. the gross value added by these jobs to the EU economy) is expected to increase from **around €486m in 2024 to almost €50bn in 2035.** The relative ranking of different countries in Europe is expected to remain similar over time, both at the top and the bottom of the distribution, with a couple of exceptions: Italy is expected to overtake France, and Finland is expected to overtake Poland and the Netherlands. This is due to particularly large expected increases in the volume of ECBDFs that will be processed in Italy and Finland in the future.

Table 4.13 Economic value of jobs generated by ECBDFs in each country (€m)

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	216	309	2,173	16,741	49,372,029
France	65	86	627	5,567	15,565,751
Italy	56	93	821	7,757	21,203,986
Sweden	30	49	406	3,751	10,352,353
Spain	28	49	422	3,857	10,657,460
Netherlands	27	40	344	2,792	8,017,632
Poland	13	22	169	1,197	3,627,214
Finland	11	21	271	3,099	7,972,430
Belgium	10	19	178	1,439	4,137,327
Denmark	7	15	125	994	2,876,602
Austria	6	15	175	2,011	5,169,147
Ireland	5	7	27	115	442,192
Czechia	3	5	55	409	1,200,687
Portugal	2	3	41	372	1,020,482
Greece	2	4	36	340	926,228
Hungary	1	2	18	141	408,769
Romania	1	1	8	52	166,293
Croatia	0.4	1	7	65	180,409
Bulgaria	0.2	0.4	5	43	118,684
Estonia	-	-	-	-	-
Cyprus	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Slovenia	-	-	-	-	-
Slovakia	-	-	-	-	-
United Kingdom	212	308	2,001	13,817	42,411,553
Switzerland	25	30	216	2,138	5,779,724
Norway	20	21	145	1,230	3,490,156
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Total EU	**484**	**741**	**5,909**	**50,742**	**143,415,674**
UK	212	308	2,001	3,817	42,411,553
Total EFTA	**45**	**51**	**361**	**3,368**	**9,269,880**
Total Europe	**741**	**1,099**	**8,271**	**67,927**	**195,097,107**
Average EU	18	27	219	1,879	5,311,692

ii. GHG emissions

With regard to GHG emissions, we estimate that, in 2023, ECBDFs are associated with approximately 1.7m tonnes of CO2-equivalent (CO2e) emissions in the EU, 150,000 tonnes of CO2e in EFTA countries, and just over 600,000 tonnes of CO2e in the UK. The total across Europe (EU + EFTA + UK) in 2023 is 2.5m tonnes of CO2e. These are significant amounts – 1.7m tonnes of CO2e is equivalent to the per capita CO2 emissions of around 310,000 people in the EU.[89] However, they are relatively small amounts compared to overall

89 According to the World Bank, average CO2 emissions per capita in the EU are 5.5 tonnes of CO2e per year. https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=EU

European carbon emissions – for context, the EU transport sector generated around 800m tonnes of CO2e emissions in 2023.[90]

A large majority of these emissions (around 83%) are generated by the processing of ECBDF cloud data centres, with the remaining 17% generated by the flow of ECBDFs through connectivity infrastructure.

These figures are expected to increase substantially over time: the estimated emissions in the EU in 2035 are almost 59m tonnes of CO2e. This is mainly due to the fact that ECBDFs are expected to increase by a factor of nearly 200 by 2035, as discussed in more detail in Chapter 2. As a result, a significantly larger volume of ECBDFs is expected to generate a significantly larger amount of negative externalities, even under the assumption that data centres and connecting infrastructures will become more energy efficient over time. Cumulatively between 2024 and 2035, EU ECBDFs will generate around 235bn tonnes of CO2e emissions.

Figure 4.19 below reports our results for 2023, and Table 4.14 shows predicted emissions in following years.

The countries that are most affected by these environmental externalities are those which receive material flows of ECBDFs (from within the country and/or other geographies) like Germany, Italy and the Netherlands and those where electricity generation is particularly carbon intensive, like Poland. Conversely, the countries that do not host main or edge cloud facilities and therefore see only outflows of ECBDFs are not expected to be affected by these GHG emissions.

Figure 4.19 GHG emissions associated with ECBDFs (tonnes of CO2e), 2023

[90] https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport

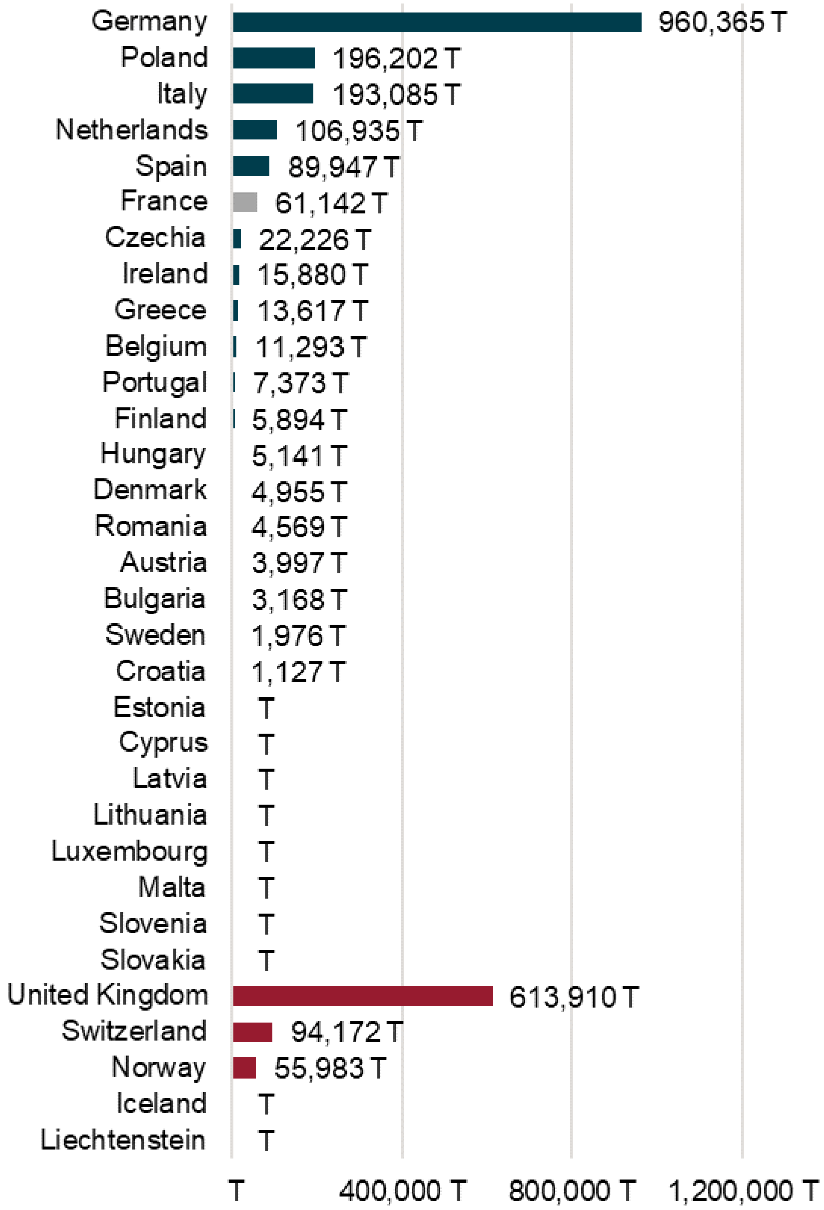


Table 4.14 GHG emissions attributable to ECBDFs in each country (tonnes of CO2e) – forecasts 2024-2035

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	1,293,899	1,693,199	503,361	22,255,074	94,557,950
Poland	338,771	569,030	228,198	13,088,347	49,370,300
Italy	294,361	446,225	155,570	8,477,110	32,697,878
Netherlands	149,262	205,233	68,464	3,146,146	13,112,276
Spain	140,066	217,112	72,001	3,561,866	14,316,576
France	75,747	90,700	27,507	1,465,651	5,734,612
Czechia	35,686	55,633	26,090	1,464,906	5,591,402
Ireland	22,191	30,769	10,379	541,638	2,131,884
Greece	23,964	40,799	16,024	873,990	3,364,329
Belgium	19,682	33,214	12,582	603,111	2,460,185

Portugal	11,337	17,103	7,351	370,648	1,481,377
Finland	10,420	18,222	8,734	640,537	2,205,565
Hungary	8,283	12,960	6,222	370,620	1,381,201
Denmark	10,144	18,952	7,054	358,964	1,420,932
Romania	7,344	11,604	6,156	445,779	1,541,780
Austria	10,093	21,585	9,513	627,448	2,233,812
Bulgaria	4,990	7,702	3,620	211,508	794,287
Sweden	2,964	4,436	1,585	94,027	349,944
Croatia	1,781	2,768	1,386	92,899	330,941
Estonia	-	-	-	-	-
Cyprus	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Slovenia	-	-	-	-	-
Slovakia	-	-	-	-	-
United Kingdom	838,596	1,132,716	339,376	14,767,906	63,166,904
Switzerland	109,326	115,595	32,572	1,792,417	6,943,254
Norway	62,845	62,335	17,293	880,537	3,541,008
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Total EU	**2,460,985**	**3,497,246**	**1,171,799**	**58,690,267**	**235,077,229**
UK	838,596	1,132,716	339,376	14,767,906	63,166,904
Total EFTA	**172,171**	**177,929**	**49,866**	**2,672,954**	**10,484,261**
Total Europe	**3,471,752**	**4,807,892**	**1,561,041**	**76,131,127**	**308,728,394**
Average EU	91,148	129,528	43,400	2,173,714	8,706,564

Figure 4.20 and Table 4.15 below report the economic value of the emissions attributable to ECBDFs in 2023, and in 2024, 2030, 2035 respectively.

We estimate the economic value of GHG emissions using the expected future price of emissions allowances (EUA) traded on the European Union's Emissions Trading Scheme (ETS), as recorded in the GHG Market Sentiment Survey 2023 conducted by PwC on behalf of IETA[91]: €84.40 per tonne of CO2e until 2026, €100 per tonne of CO2e from 2026 to 2036.[92]

In 2023, the total value of these emissions in the EU was a cost of **€143m**; for EFTA countries, it was a cost of **€13m**, and for the UK **€42m**. The total for Europe was nearly **€200m.** These costs are expected to increase substantially over time: for the EU, to almost **€5.9bn** in 2035. These values are presented as positive in the figure and tables below, but need to be subtracted from the total value estimated in previous sections as they represent a social cost (the cost to society of GHG emissions).

91 The International Emissions Trading Association (IETA) is a non-profit business group that champions the power of high integrity markets to reach net-zero targets.

92 https://k5x2e9z8.rocketcdn.me/wp-content/uploads/2023/09/IETA_GHGSentimentSurvey_2023.pdf

Looking at the cost of these externalities by country, we can see that it is especially high in the UK and Germany. This is explained by the high net inflows of ECBDFs into these two countries.

Like the UK and Germany, France is also a net recipient of large volumes of ECBDFs; however, the carbon intensity of electricity generation in France is much lower than in the UK and Germany, which results in much lower GHG emissions generated by ECBDFs in France throughout the 2023-2035 period.[93]

Similarly, the high position of Poland in this relative ranking is driven by the high carbon intensity of electricity generation in this country and highlights an important caveat of these estimates, which are based on standard assumptions with regard to future energy efficiency improvements (1.9% pa constant) and carbon intensity of electricity generation in each country (linear interpolation of past trends).

Conversely, the value of the environmental externality is zero in many countries that do not process ECBDFs and therefore do not require energy generation for that processing.

However, it is important to note that forecasting the future carbon intensity of electricity generation in different countries is a highly intricate task due to the multifaceted nature of the energy landscape. While our methodology does include forecasting a decrease in future carbon intensity (detailed in Section 3.3 of the methodological note), several factors contribute to the complexity of this endeavour, including the dynamic mix of energy sources, policy changes, technological advancements and economic shifts.

Each country possesses a unique energy portfolio, with a blend of fossil fuels, renewable energy and nuclear power sources, making it challenging to predict how these elements will evolve over time. The shifting political and regulatory landscape further complicates predictions, as governments may introduce new policies or amend existing ones to address environmental concerns or economic priorities. Additionally, technological advancements, such as breakthroughs in energy storage or improvements in renewable energy efficiency, can significantly alter the trajectory of carbon intensity, but these innovations are often unpredictable in terms of their timing and widespread adoption.

[93] Generating 1 MWh of electricity generates on average 68 kg of CO_2, compared to 366 in Germany and 251 in the UK. Source: https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1.

Figure 4.20 Economic value of GHG emissions of ECBDFs in each country (€m), 2023

Table 4.15 Economic value of GHG emissions of ECBDFs in each country (€m) – forecasts 2024-2035

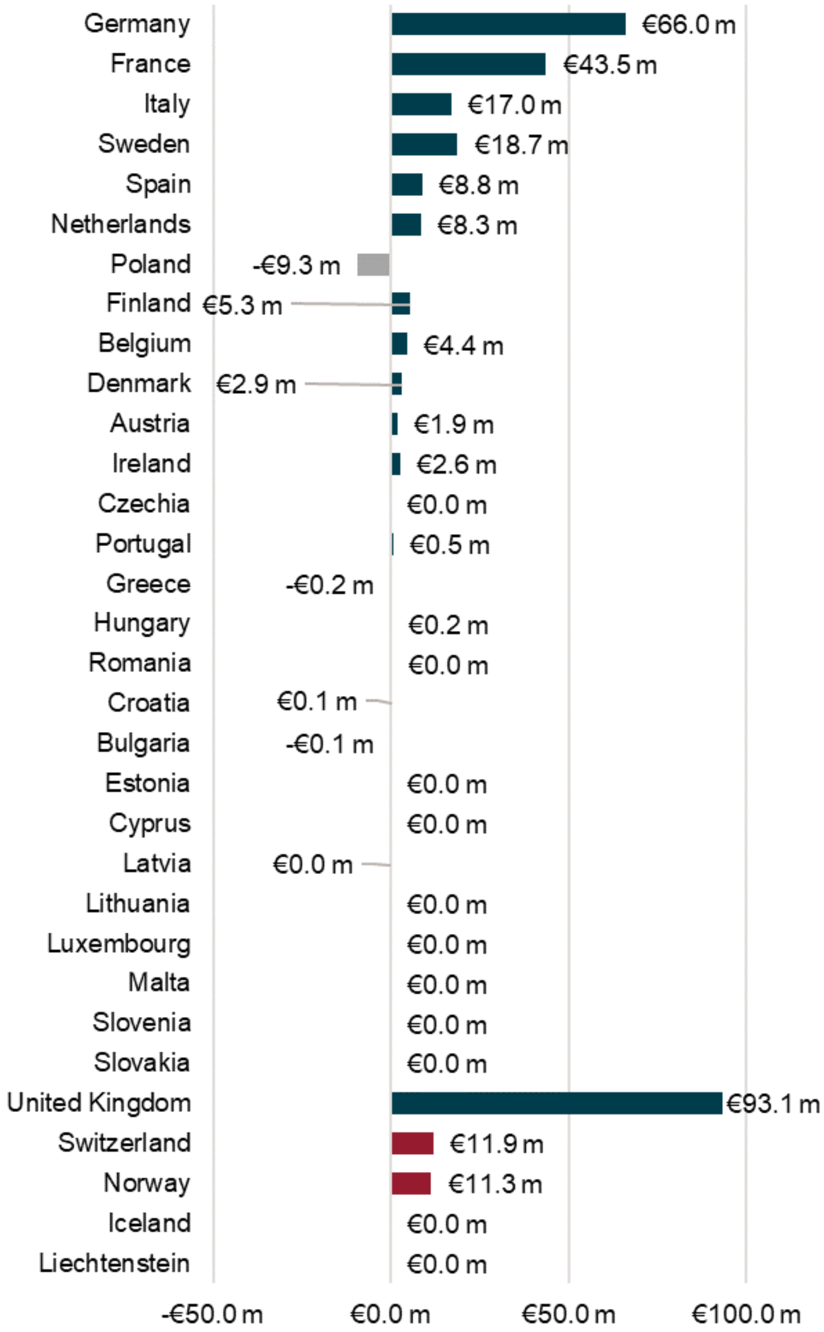
Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	109	143	636	2,226	9,374,374
Poland	29	48	307	1,309	4,909,502
Italy	25	38	204	848	3,248,323
Netherlands	13	17	89	315	1,301,317
Spain	12	18	93	356	1,421,268
France	6	8	36	147	569,069

Czechia	3	5	36	146	556,399
Ireland	2	3	14	54	211,703
Greece	2	3	21	87	334,465
Belgium	2	3	17	60	244,419
Portugal	1	1	10	37	147,300
Finland	1	2	12	64	219,663
Hungary	1	1	9	37	137,481
Denmark	1	2	9	36	141,188
Romania	1	1	9	45	153,602
Austria	1	2	13	63	222,338
Bulgaria	0.4	1	5	21	79,049
Sweden	0.3	0.4	2	9	34,780
Croatia	0.2	0.2	2	9	32,957
Estonia	-	-	-	-	-
Cyprus	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Slovenia	-	-	-	-	-
Slovakia	-	-	-	-	-
United Kingdom	71	96	431	1,477	6,262,335
Switzerland	9	10	42	179	688,700
Norway	5	5	23	88	351,057
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Total EU	**208**	**295**	**1,524**	**5,869**	**23,339,195**
UK	71	96	431	1,477	6,262,335
Total EFTA	**15**	**15**	**65**	**267**	**1,039,757**
Total Europe	**293**	**406**	**2,020**	**7,613**	**30,641,287**
Average EU	8	11	56	217	864,415

iii. Total economic value of externalities

The final chart of this chapter shows the combined value of the two externalities discussed above, in 2023, broken down by country. An overview of the total value estimated across the three dimensions discussed above (demand, supply and externalities) is provided in Chapter 5.

Figure 4.21 Economic value of ECBDF externalities (job impacts and GHG emissions, €m), 2023



The overall economic value of these externalities in 2023 for the EU was approximately €171m (€345 value of jobs minus €144 value of CO2e emissions). For EFTA, it was around €23m; for the UK, it was around €93m; and for Europe as a whole it was around €287m.

In some countries where the economic value added by direct, indirect and induced jobs is comparatively low, the combined value was negative due to the cost of environmental externalities being larger than the value generated through jobs associated with ECBDFs. This is the case for Poland, Greece and Bulgaria (once again, countries with high carbon intensity of electricity generation).

However, as shown in Table 4.16 below, this number decreases after 2030, as a result of energy efficiency and improvements in the carbon intensity of electricity generation driving down the cost of environmental externalities relative to the value of jobs.

Overall, between 2024 and 2035, the cumulative value generated to the EU economy in terms of externalities is estimated to be positive, at around **€120bn (**€143bn value of jobs minus around €23bn value of CO2e emissions). In absolute terms, the value of jobs is five times the value of CO2e emissions.

The cumulative value to Europe as a whole, including EU, EFTA and UK over the same period (2024-2035) is €164bn.

Table 4.16 Economic value of ECBDF externalities (job impacts and GHG emissions, €m), forecasts 2024-2035

Country	2024	2025	2030	2035	Cumulative 2024 to 2035
Germany	106	166	1,537	14,515	39,997,656
France	59	78	591	5,420	10,656,249
Italy	31	55	617	6,909	17,955,663
Sweden	30	49	404	3,742	9,051,036
Spain	16	30	329	3,501	9,236,192
Netherlands	14	23	254	2,477	7,153,218
Poland	- 16	- 26	- 138	- 112	3,070,815
Finland	10	20	259	3,035	7,760,726
Belgium	9	16	161	1,378	3,802,862
Denmark	6	13	116	958	2,632,183
Austria	5	13	163	1,949	5,021,848
Ireland	3	4	14	61	222,529
Czechia	0.2	1	18	263	1,063,207
Portugal	1	2	31	335	879,294
Greece	-0.2	0.1	15	252	772,626
Hungary	0.4	1	9	104	186,431
Romania	0.1	0.1	-0.5	8	87,243
Croatia	0.2	0.4	5	56	145,628
Bulgaria	-0.2	-0.3	-0.3	22	85,726
Estonia	-	-	-	-	-
Cyprus	-	-	-	-	-
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	-	-
Malta	-	-	-	-	-
Slovenia	-	-	-	-	-
Slovakia	-	-	-	-	-
United Kingdom	141	212	1,571	12,340	36,149,218
Switzerland	16	20	174	1,959	5,091,024
Norway	14	16	122	1,142	3,139,099
Iceland	-	-	-	-	-
Liechtenstein	-	-	-	-	-
Total EU	**276**	**446**	**4,384**	**44,873**	**120,076,478**
UK	141	212	1,571	12,340	36,149,218
Total EFTA	**30**	**36**	**296**	**3,100**	**8,230,123**
Total Europe	**447**	**693**	**6,251**	**60,313**	**164,455,820**
Average EU	10	17	162	1,662	4,742,623

5. Conclusions

This report includes our estimates of the current and future volume and value of enterprise cloud-based data flows (ECBDFs) that originate from enterprises that use cloud services located in the EU, the UK and EFTA countries.

Our estimates of **the volume, origin and destination of ECBDFs** are based on an updated methodology evolved from the approach taken by previous studies, with a novel extension which estimates the proportion of ECBDFs that flow to non-European countries.

Our estimates of **the economic value of ECBDFs** are based on a new conceptual framework and empirical approach, which, for the first time, attempts to identify the proportion of the economic value of cloud services attributable to ECBDFs specifically. Our framework is based on microeconomic theory and it includes an approach to estimating: i) the value of ECBDFs to enterprises that use cloud services (demand-side value); ii) the value of ECBDFs to cloud service providers (supply-side value); iii) the value of externalities linked to ECBDFs, including the jobs and GHG emissions created in the telecommunications network to support the flow of data and in the cloud data centres that receive the ECBDFs.

a. Overview of our key findings – volume and value of ECBDFs

We estimate that cumulatively European (EU, EFTA and UK) enterprises generated around **42,019 PB/year of ECBDFs** in 2023, and will generate 719,000 PB/year in 2030 and 7.2m PB/year in 2035. The 2023 estimate for the EU only is **30,000 PB/year of ECBDFs;** for EFTA without the UK, it is **1,150 PB/year of ECBDFs; and for the UK, it** is **11,044 PB/year of ECBDFs.**

The volume of ECBDFs is expected to increase substantially over time, as shown in Table 5.1 below, by approximately 20 times in 2030 compared to 2023 in the EU.

Table 5.1 Volume of ECBDFs in Europe, 2023, 2030 and 2035 (PB/year)

	2023	2030	2035
EU	29,822	588,926	5,559,233
EFTA	1,153	20,311	185,946
UK	11,044	178,243	1,440,618
Total Europe (EU + EFTA + UK)	**42,019**	**787,479**	**7,185,797**

We also find that ECBDFs generate a significant amount of **economic value**. In 2023, we estimate that the economic value of ECBDFs to Europe was around **€91.6bn,** of which **€65.2bn was in the EU, €7.1bn was in EFTA countries, and €19.3bn was in the UK**. The value of ECBDFs is also expected to increase substantially over time by approximately three times in 2030 compared to 2023 in the EU. This demonstrates that the volume and value of ECBDFs do not have a single, one-to-one linear relationship.

Table 5.2 Economic value of ECBDFs in Europe, 2023, 2030 and 2035 (€m)

	2023	2030	2035
EU	65,191	174,478	328,175
EFTA	7,148	15,696	26,996
UK	19.295	38,666	64,972
Total Europe (EU + EFTA + UK)	**91,635**	**228,840**	**419,963**

The economic value of ECBDFs in the EU in 2023 includes:

- About **€58.6bn of demand-side value:** additional GVA generated by European enterprises, as a result of ECBDFs;
- About **€6.4bn of supply-side value:** profits realised by cloud service providers, attributable to the role of ECBDFs; and
- Around **€0.2bn** value from externalities, which includes €0.3bn value of job creation linked to ECBDFs and a negative €0.1bn value representing the environmental cost of GHG emissions linked to ECBDFs. A large majority of both jobs (over 99%) and emissions (over 80%) is generated by cloud data centres (including edge) in the country of destination of ECBDFs. The remaining value (less than 1% of jobs and 20% of emissions) is linked to the installation, operation and maintenance of connecting infrastructure in the country of destination (i.e. through cables, exchange stations, servers and switches).

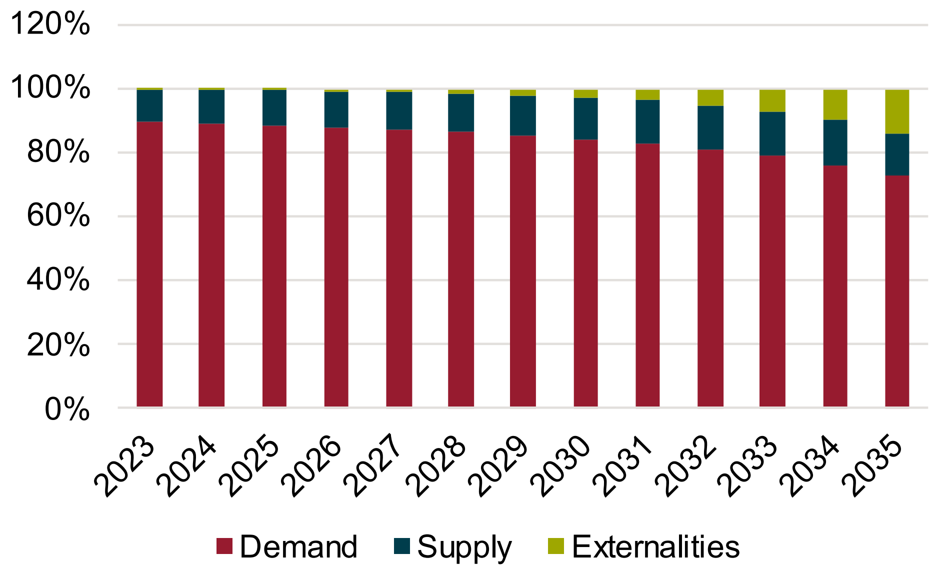
Table 5.3 below shows the expected demand-side value, supply-side value and value of externalities in the EU in 2023, 2024, 2030 and 2035.

Table 5.3 Economic value of ECBDFs in Europe, 2023, 2030 and 2035 (€m)

	2023	2024	2030	2035
Demand-side value	58,630	69,178	147,218	328,175
Supply-side value	1,987	7,860	22,875	44,027
Value of job creation	315	484	5,909	50,742
Value of GHG emissions	-144	-208	-1,524	-5,869
Total value of ECBDFs	**65,191**	**77,314**	**174,478**	**328,175**

As shown in Figure 5.1 below, we expect that the value of externalities from ECBDFs will account for an increasing proportion of the total value of ECBDFs in Europe between 2023 and 2035. This is mainly due to the fact that externalities (in particular, the value of jobs linked to ECBDFs in cloud data centres and connecting infrastructure) are directly driven by the volume of ECBDFs, which is estimated to increase dramatically over the period of analysis. Conversely, the demand- and supply-side values are estimated to grow less exponentially over time, but with demand-side value always being higher than supply-side value. Our forecasts indicate that the total value of externalities from ECBDFs (which adds up the positive value of job creation and the negative value of GHG emissions) is likely to be larger in 2035 than the supply-side value of ECBDFs, albeit with a significant degree of uncertainty.

Figure 5.1 Relative weight of different drivers of value over time Europe (EU + EFTA + UK), 2023-2035



Our study also estimates and forecasts how the volume and value of ECBDFs vary by country, by sector and by firm size.[94]

b. ECBDF volume and value by country

Figure 5.2 below shows the share of the total volume of European ECDBFs accounted for by each country of origin in 2023, and the same for the economic value of ECBDFs. This shows **that Germany and the UK accounted for the largest proportion of volume and economic value** (7,000 PB/year and €18bn for Germany and 11,000 PB/year and €19.2bn for the UK).

In some cases, **countries that generate a higher volume of ECBDFs generally also realise greater value from these flows**. These are cases where the blue and red bars for the country are of a similar length in Figure 5.2 below, (as in the case of Belgium, Germany and Italy). Germany's DFCI value is just above the EU average (56% versus 50%).

However, the relation between volume and value is still complex and there are:

- **Countries that generate relatively large value compared to their volume of ECBDFs (such as Finland, Ireland, the Netherlands, Norway, Sweden and Switzerland)**; and
- **Countries that generate relatively small value compared to their volume of ECBDFs (such as France, Poland, Spain and the UK).**

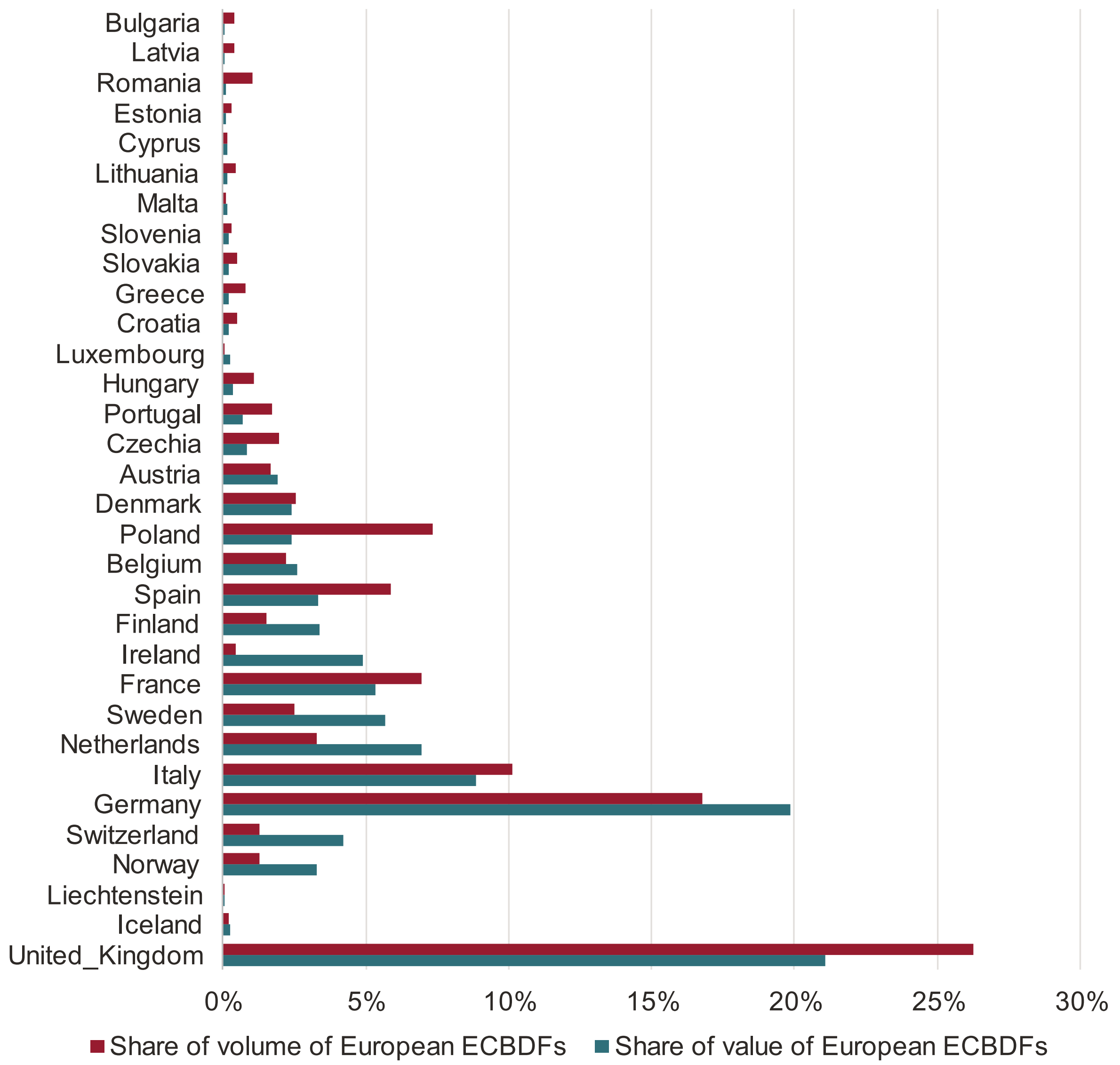
The first group consists of relatively smaller economies where a relatively high proportion of enterprises undertake activities for which ECBDFs are critical, such as using AI, analysing very large cloud-based datasets or interacting with customers through digital cloud-based interfaces. The annual economic value of ECBDFs for these countries in 2023 was €3bn for Norway, €3.1bn for Finland, €3.8bn for Switzerland, €4.5bn for Ireland, €5.2bn for Sweden and €6.4bn for the Netherlands.

[94] We also estimate how the value of ECBDFs varies by type of cloud service, but we do not report this in this section as it was not possible to estimate how the volume of ECBDFs varies by cloud service type.

Conversely, the second group includes two distinct cases: France, Poland and Spain on the one hand, and the UK on the other.

France, Poland and Spain are all large countries where ECBDFs account for a low to moderate proportion of the value that enterprises draw from their use of cloud services (28% on average for Poland, 41% for France and 43% for Spain, as measured by our DFCI index[95]). The size of their economies explains why they generate a relatively large volume of ECBDFs. However, their DFCI values indicate that these ECBDFs are not as critical for their enterprises to generate value, compared to the case of Nordic countries, Ireland and Switzerland (DFCI values of 71% for Denmark, 67% for Finland and Ireland, 60% for Switzerland). Therefore, while France, Poland and Spain do generate significant amounts of value from ECBDFs (€716m for Poland, €3bn for Spain and €3.6bn for France in 2023), the value generated is smaller than it would be if they made a more efficient use of cloud-based capabilities.

Figure 5.2 Country shares of the total volume and value of ECBDFs in Europe, 2023



95 The DFCI is a composite index that we use to approximate the importance of ECBDFs to the optimal use of cloud-based services (and therefore, to users' willingness to pay for cloud services) and the importance of ECBDFs in cloud providers' ability to run their operations optimally.

The UK's case is similar to the rest of this group, but the UK accounts for both a much higher volume and value of ECBDFs (11,000 PB/year and €19.3bn in 2023, respectively). This is because, compared to France, Poland and Spain, the UK has considerably higher internet traffic (which contributes to volume[96]), cloud uptake (which contributes to volume and value) and a higher DFCI (which contributes to value). However, like the rest of this group, the UK's DFCI (55%) value is significantly lower than that of Denmark, Ireland, Finland, Sweden, Iceland and Switzerland. This indicates that the UK could gain more value from the ECBDFs given the volume it generates. Moreover, the UK's productivity growth has been slow in recent years compared to international benchmarks, which may suggest that the UK has not been able to translate digitalisation into greater productivity to the same extent as other countries.[97]

Our forecasts suggest that the picture shown in Figure 5.2 above is likely to remain similar in 2030 and 2035.

We also find no evidence that whether a country is a net receiver of more ECBDFs from other countries (or vice versa, a net sender of more ECBDFs to other countries) has an effect on the value associated with ECBDFs in that country (as shown in the scatter plot below, where each dot on the chart is a European country). This confirms one of the key pillars of our analytical framework – the fact that the value of a given PB of ECBDF varies significantly on a case-by-case basis, and there is no simple linear relationship between volume and value, even though the volume of ECBDFs is a key driver of the externalities value.

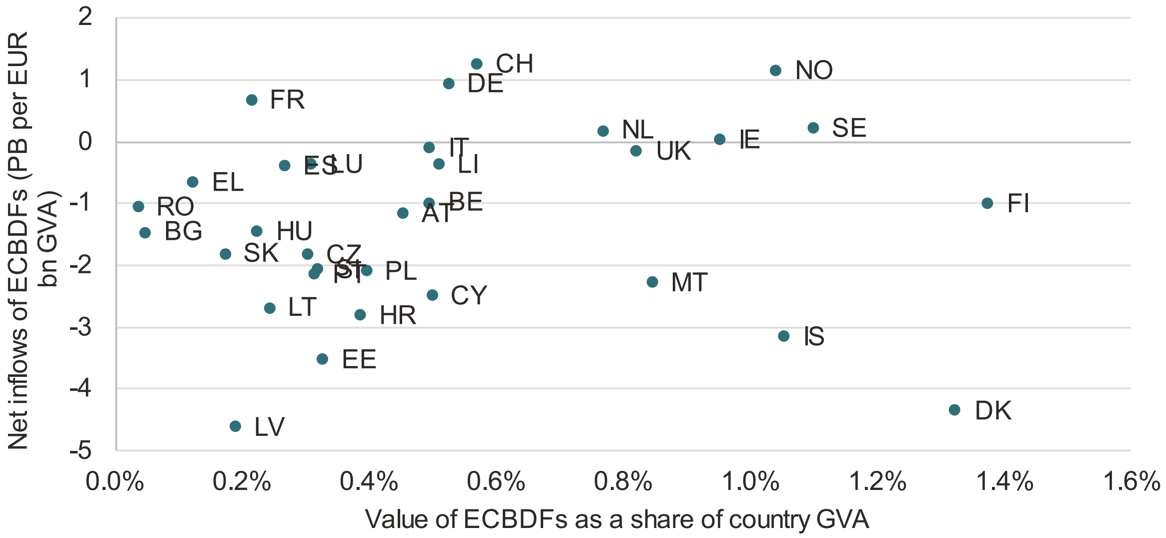
Indeed, most countries in Europe have negative net inflows of ECBDFs (they are below the horizontal axis in the plot below), regardless of whether they realise a relatively high value from ECBDFs (as in the case of Denmark, Finland and Sweden, shown on the right-hand side of the chart), or a relatively low value from ECBDFs (as in the case of Bulgaria, Greece and Romania, shown on the left-hand side of the chart). This is because the value that an organisation can extract from ECBDFs is driven by the value that these flows add to the economic activities that this organisation performs on the cloud and not on the volume of flows per se.

[96] The specific case of the UK (and a comparison with Germany: the larger country under analysis in terms of population) is helpful in explaining the methodology adopted in this report to estimate the volume of ECBDFs generated by each country. More specifically, although Germany has a larger population and greater number of employees than the UK, the UK has a larger average cloud uptake rate across NACE sectors, as well as a higher level of internet traffic per employee. This results in a larger estimated volume of ECBDFs.

Examining these countries in more detail, the number of employees in Germany (40 million) is marginally higher (1.25x) than the UK (32 million). However, the average cloud uptake across all sectors (weighted by the number of employees in each sector) is significantly higher (1.5x) for the UK compared to Germany. This results in the estimated number of employees using cloud services being higher (1.2x) for the UK (22 million), compared to Germany (18 million). The UK's greater magnitude relative to Germany is extended when average internet use per employee is applied, because the UK rate is 1.60x higher than Germany's, at 0.00091 PB per employee, compared to 0.00057 PB per employee. As a result, the final volume of ECBDFs for the UK is approximately 1.9x that of Germany's.

[97] For a comparison of UK productivity against other countries, see for example: https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/bulletins/internationalcomparisonsofproductivityfinalestimates/2021#:~:text=Output%20per%20hour%20worked%3A%20direct,when%20using%20the%20direct%20method.

Figure 5.3 Comparison of net inflows and ECBDF value for each European country, 2023



c. Volume and value by sector and firm size

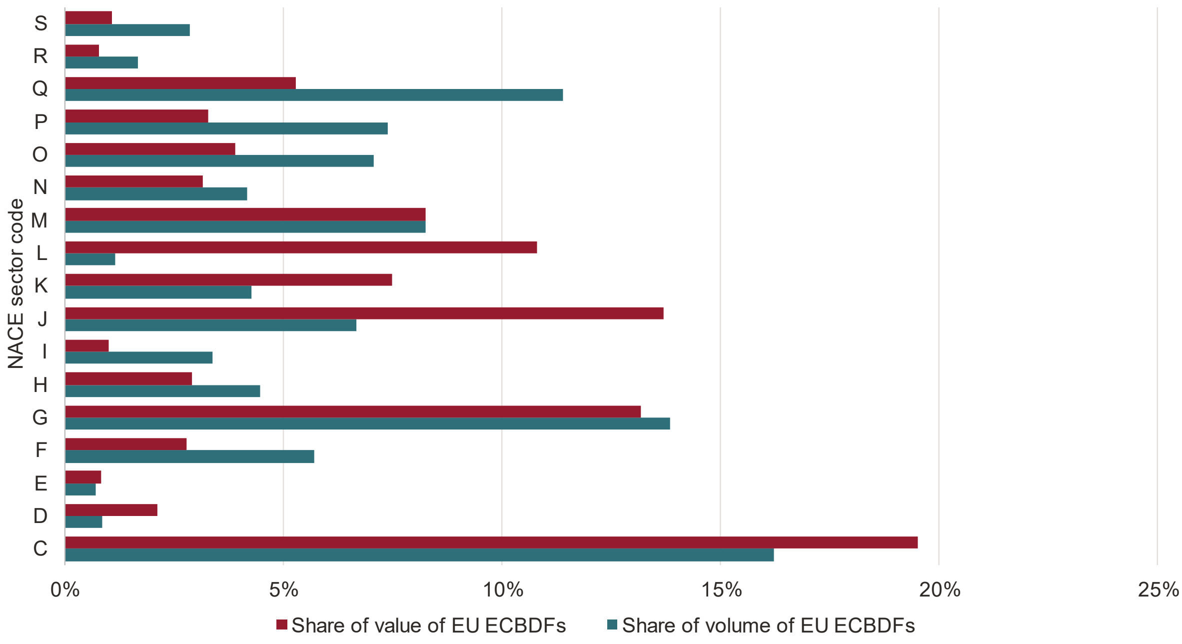
We find that large enterprises account for a majority of the volume (around 60%) and enterprise value (56%) of ECBDFs, taking account of both value realised by cloud-using enterprises and by cloud providers. However, this is partly driven by the fact that cloud providers are almost exclusively large businesses, and the value of EU ECBDFs to cloud providers in 2023 was around €6bn. **The value of ECBDFs to cloud-using enterprises in the EU (€58.6bn) is split roughly equally between SMEs (€28.9bn) and large enterprises (€29.7bn).**

This report also estimates the volume of ECBDFs by sector of origin and the value of ECBDFs to the user enterprises in those sectors. As shown in Figure 5.4, in general, sectors that account for a greater proportion of ECBDF volume also account for a greater proportion of value. For example, **the manufacturing sector (NACE code C) is highest** in terms of both volume and value, while electricity, gas, steam and air conditioning (NACE code D), arts, entertainment and recreation (NACE code R), and other service activities (NACE code S) are in the bottom five in terms of both metrics.

However, as in the case of country-level results, there are significant exceptions to this pattern. The clearest is real estate (NACE sector code L), which accounts for over 10% of the EU user-side value of ECBDFs (€6.3bn out of €58.6bn in 2023) but only 1% of the volume of ECBDFs (344 PB/year out of 29,822 PB/year in 2023). A possible explanation for this exception is the high capital intensity of this sector, which means that there are relatively few workers using data, and consequently cloud-based services in the sector, and generating ECBDFs in the process, but the data relates to large amounts of assets and therefore is linked with high GVA. Other discrepancies between volume and value are explained by cross-sector differences in DFCI scores, which indicate that ECBDFs are more critical for value generation in some sectors compared to others:

- On the one hand, finance and insurance (NACE code K) and information and communication (NACE code J), sectors where ECBDFs are highly critical according to our DFCI estimation, account for a larger proportion of the EU value of ECBDF compared to volume;
- On the other hand, education (NACE code P) and health (NACE code Q) are sectors where ECBDFs are less critical according to our DFCI estimation and therefore the user value realised from ECBDFs is relatively low compared to the volume of ECBDFs generated.

Figure 5.4 Sector share of the volume and value of ECBDFs in the EU, 2023



Note: C=Manufacturing; D=Electricity, Gas, Steam and Air Conditioning Supply; E=Water Supply; Sewerage, Waste Management and Remediation Activities; F=Construction; G=Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles; H=Transportation and Storage; I=Accommodation and Food Service Activities; J=Information and Communication; K=Financial and Insurance Activities; L=Real Estate Activities; M=Professional, Scientific and Technical Activities; N=Administrative and Support Service Activities; O=Public Administration and Defence; Compulsory Social Security; P=Education; Q=Human Health and Social Work Activities; R=Arts, Entertainment and Recreation; S=Other Service Activities. Sectors A (Agriculture, Forestry and Fishing) and B (Mining and Quarrying) are not included in the analysis as there is no data on cloud uptake available on Eurostat and none of the other sectors is sufficiently comparable to generate a proxy.

We also find that large enterprises accounted for **around 56% of the volume of ECBDFs that originated from European countries in 2023**. SMEs account for the remaining 44%. However, SMEs account for a slightly larger proportion of ECBDF user-side value (49%). This is because the impact of ECBDFs on the productivity of SMEs is greater than in the case of large enterprises.[98]

d. Destination of ECBDFs and value at stake from Extra-EU ECBDFs

Our estimates of the volume and location of ECBDFs also included an analysis of the destination of ECBDFs.

We estimate that, in 2023, around 53% of ECBDFs that originated in the EU stayed within the country of origin, with 30% flowing to other European countries and the remaining 17% to other regions. There is significant variation around this average. For example, 80% of the ECBDFs generated in Germany are estimated to have remained within Germany. On the other end of the spectrum, 100% of the ECBDFs generated by small countries like Cyprus, Latvia, Lithuania and Luxembourg are assumed to have flowed to other countries. This volatility is driven by the

[98] This results in turn from existing evidence from Gal et al. (2019) that the impact of cloud uptake on the GVA of cloud-using enterprises is higher for SMEs than for large enterprises. This could be due to the fact that large enterprises are better able than SMEs to carry out fixed investment in IT hardware or software in the absence of cloud use, and therefore may have less to gain from cloud use compared to SMEs.

fact that most cloud providers have main cloud centres and edge facilities in large countries like Germany and France, while the small countries listed above do not appear to have such cloud facilities, which means that all ECBDFs are estimated to flow to other countries.

ECBDFs flow from enterprise locations to two types of data centres: “main” and “edge” data centres. “Edge” data centres are located close to the enterprises that generate ECBDFs and their customers, to minimise latency and for data residency requirements. We estimate that, in 2023, approximately **20,300 PB/year of EU ECBDFs flowed to main data centres, and 9,500 PB/year flowed to edge data centres.**

While it was not possible to estimate precisely the economic value of ECBDFs that flowed from one geography to others,[99] our geographical analysis of ECBDF value implies that, of the **€58.6bn of value of ECBDFs realised by cloud-using enterprises in the EU (i.e. user-side or demand-side value), around €13.2bn are linked to ECBDFs between enterprises located in the EU and cloud data centres in countries outside the EU. Of these €13.2bn, €10bn are linked to ECBDFs from the EU to cloud data centres located outside Europe, €2.7bn are linked to ECBDFs from the EU to EFTA countries, and €0.5bn are linked to ECBDFs from the EU to the UK.**

e. Future forecasts

i. Volume

Looking to the future, the volume of ECBDFs that originate from EU enterprises is expected to increase very rapidly over the next 10-15 years. Based on recent rates of increase, **we estimate that the ECBDFs generated in 2035 in the EU could reach around 5.6 million PB/month, representing a 190x increase compared to the estimate for 2023.** This is consistent with market expectations in relation to the widespread adoption of emerging technologies, such as the IoT and 5G connectivity, and suggests that the importance of digital infrastructure for Europe, particularly data centres and connectivity infrastructure to and from those data centres, is going to increase in the future.

This increase in the volume of ECBDFs also poses significant challenges from an environmental perspective for the EU. We estimate that the GHG emissions linked to the transfer and processing of ECBDFs will increase from the current 1.7m tonnes of CO2e to about 59m tonnes of CO2e in 2035. These estimates incorporate some standard assumptions in relation to energy efficiency (which are explained in more detail in the methodological note), which is why GHG emissions are estimated to grow more slowly than the total volume of ECBDFs.

At the same time, the proportion of EU ECBDFs that flow to other regions is expected to decrease over time due to the growing role that edge data centres are expected to play. This is also one of the reasons why the proportion of ECBDFs that flow to other regions is estimated to fall to 10% in 2035 from 18% in 2023. The destination of these extra-European ECBDFs that originate from the EU is assumed to be constant over time, due to lack of suitable data to forecast different destinations over time, but future research might want to explore this aspect further.

ii. Economic value

Along with increasing volumes of ECBDFs over time, we also expect an increase in the value of these flows, rising from €65.2bn in 2023 to around €328bn in 2035. This is an increase by a factor of 5, much less than the predicted increase in volume of ECBDFs (around 190x, as described below).

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[99] Please see our methodology note accompanying this report for further discussion.

This is consistent with an expectation that, at a macro level, the marginal returns to additional ECBDFs are decreasing over time. In other words, the expectation that the value of an additional exabyte of ECBDF in 2035 will be lower than it is in 2023. This appears reasonable in a context where the overall volume of data produced, stored and analysed is expected to increase by several orders of magnitude compared to the present day. However, it is possible that, in the future, the emergence of new data-intensive technologies that have a very large impact on productivity would lead the value of ECBDFs to increase further compared to what we predict in this study.

Our forecasts indicate that the distribution of economic value of ECBDFs between European countries, sectors and firm sizes in future years will remain similar to the current distribution. The volume and value of ECBDFs in some of the countries where these are currently relatively small (such as the Baltics) are expected to grow particularly quickly as these countries' cloud uptake catches up to others. However, this growth is not sufficiently fast to change substantially the overall ranking of European countries in terms of the volume of ECBDFs generated and in terms of the value of these flows.

Within the EU, Germany, Italy, Netherlands, Ireland and Sweden and France are expected to remain among the top countries in terms of the value of ECBDFs generated, with France overtaking Sweden due to faster expected future growth in the uptake of cloud services. On the other hand, Bulgaria, Latvia, Romania, Cyprus and Estonia are expected to remain the five countries that generate the lowest value of ECBDFs, again primarily due to the size of their economies.

f. Strategic implications for future use of our framework analysis

Together with the VVA report and the Ipsos/Tech4i2 report, this study delivers one of the key actions of the EU Data Strategy: ***"the creation of a framework to measure data flows and estimate their economic value within Europe as well as between Europe and the rest of the world".*** In particular, this report provides novel economic intelligence in the cloud and edge computing field to enable evidenced-based policy and investment decisions, including **estimates of the volume of ECBDFs that flow to other regions**.

In addition, the methodology and the conceptual framework presented in this report provide a new and innovative way to isolate the economic value of ECBDFs from the value of cloud services more generally. To our knowledge, this report includes the first conceptual framework to focus on ECBDFs based on economic theory.

As mentioned in Chapter 1, the results presented in this report are exploratory and based on a variety of evidence-based assumptions that can be used as a starting point for future research on ECBDFs. This future research could be applied to a variety of ex-post and ex-ante analyses of policies and investment decisions.

i. Policy insights

This economic analysis and research could be strategically used to contribute to the assessment of the EU's digital decade targets and, in particular, the cloud and edge targets which aim for 75% of EU companies to be using cloud/AI/Big Data by 2030, and for the deployment of 10,000 climate-neutral and secure edge nodes across the EU. In this case, the assumptions made to estimate future enterprise cloud usage and those that focus on the split between ECBDFs which flow to main cloud centres and edge centres appear particularly relevant. Moreover, our study estimates that the value of ECBDFs realised by enterprises that use cloud services is large relative to the value realised by cloud providers (€58.6bn versus €6.4bn). This indicates that policy actions (such as the Digital Decade's cloud target) that have an impact on cloud users may have a particularly large economic impact.

This study could inform policy discussions on the European Industrial Strategy, providing economic intelligence on the countries and the sectors where the value of ECBDFs is higher and lower as well on the location of main and edge cloud data centres and on the associated magnitude, origin and destination of cloud data flows as a key proxy to assess the strategic autonomy and resilience of the cloud-edge industrial value chain via the geographical locations of its cloud-edge physical capacities across the EU.

Our estimates could also contribute, together with other more targeted pieces of evidence, to the ex-post evaluation of the regulation (2018/1807) on the Free Flow of Non-Personal Data. In this context, it is important to note that many of the assumptions made to estimate values before 2021 are assumed to remain constant in previous years (e.g. proportion of enterprise internet traffic flowing to cloud facilities, market shares of main cloud providers, etc.). However, our estimates indicate that the volume of ECBDFs that originate from EU countries increased by 171% between 2018 (the year of the regulation's implementation) and 2023.

ii. Investment patterns

Our forecasts could also be used to make decisions on future investment in cloud and edge computing capabilities. In particular, our forecast volumes, origins and destinations of ECBDFs could complement other ad-hoc analyses and evidence on the magnitude of investment needed in different countries of the EU. This could be particularly relevant for future Multiannual Financial Framework (MFF) negotiations at EU level and, in particular, for designing, appraising and implementing evidence-based investment decisions to foster sustainable connecting infrastructures, submarine cables and cloud-edge physical capacities through which ECBDFs flow and are stored. For example, the quantitative data provided in this report could be used to allocate new investments in the above areas under digital programmes such as the Connecting Europe Facility, DIGITAL and *InvestEU* .

iii. Trade negotiations

Lastly, our estimates could be used to inform future international trade negotiations, with a particular focus on the volume of ECBDFs that flow to other regions outside Europe and to which specific countries within these regions, as well as on the estimated economic value attributed to ECBDFs.

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