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MEASURING THE DIGITAL ECONOMY AND ITS APPLICATIONS

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Mshvidobadze T. I. Measuring the Digital Economy and Its Applications

The paper provides an analysis and summary of important data from experts, researchers and statistical partners. The framework proposed in the paper consists of a digital economy measurement method based on value added calculation. The measurement method uses national accounts and reflects the digital economy in the overall context of gross domestic product (GDP). The study shows the identification of relevant digital sectors around the core perimeter of the digital economy. The given results are obtained using the data obtained from the national reports of 16 economies of different regions of the world, according to which the digital economy represents a significant part of the GDP of all the selected economies. Measuring the digital economy in terms of the economy's gross domestic product and the contribution of incremental moderation goes beyond the low-level threshold for assessing its welfare effects on the broader economy. The paper provides a comprehensive statistical perspective on the overview of the development of the digital economy. At this point, the proposed framework for measuring the digital economy tries to focus on the emerging products and industries of the digital age. Frame measures the digital economy's share of GDP attributable to the economy's total GDP, which is accounted for by the contribution of value added to a defined set of key digital products, consistent with the digital economy. The method proposed in the framework makes it extremely flexible, as users can independently obtain the appropriate results for their desired level of analysis. Digital technologies are transforming the way businesses operate and how societies interact.

Keywords: *digital economy, measurement framework, GDP, Leontief coefficient, matrix operations.*
Fig.: *3.* ***Tabl.:*** *1.* ***Formulae:*** *5.* ***Bibl.:*** *10.*

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Мшвідобадзе Т. Я. Вимірювання цифрової економіки та її застосування

У статті наведено аналіз і підсумок важливих даних, отриманих у результаті праці експертів, дослідників і статистичних партнерів. Основну частину статті складає розгляд методу вимірювання цифрової економіки на основі розрахунку доданої вартості. Метод вимірювання використовує національні рахунки та відображає цифрову економіку в загальному контексті валового внутрішнього продукту (ВВП). Дослідження презентує ідентифікацію відповідних цифрових секторів основного периметра цифрової економіки. Наведені результати отримано з використанням даних із національних звітів 16 економік різних регіонів світу, згідно з якими цифрова економіка становить значну частину ВВП усіх обраних економік. Оцінювання цифрової економіки з точки зору валового внутрішнього продукту, а також застосування інкрементної модерації стосується впливу на економічний добробут, із охопленням доволі широкого кола аспектів. У статті наведено комплексний статистичний огляд розвитку цифрової економіки. На даний момент запропонована система вимірювання цифрової економіки зосереджується на нових продуктах і галузях цифрової епохи. Проведено вимірювання внеску цифрової економіки до ВВП у відсотках до загального ВВП, який розглядається як додана вартість до визначеного набору ключових цифрових продуктів, що відповідають вимогам цифрової економіки. Запропонований метод оцінки є надзвичайно гнучким, оскільки користувачі можуть самостійно отримувати відповідні результати для бажаного рівня аналізу. Цифрові технології змінюють спосіб роботи бізнесу та взаємодію із суспільством.

Ключові слова: *цифрова економіка, система вимірювання, ВВП, коефіцієнт Леонтьєва, матричні операції.*
Рис.: *3.* ***Табл.:*** *1.* ***Формул:*** *5.* ***Бібл.:*** *10.*

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Digital technologies in the form of miniature computing, communications and storage devices now play an important role in modern life. In response, industries have begun methods to measure digitization using real-world data on private and public transactions involving digital goods and services. The collective value of such products and their associated interactions is referred to as the "digital economy".

The term "digital economy" is often associated with terms such as the internet economy, the cloud economy, the sharing economy, and the on-demand economy. Although each relates to business activities, common among them is the use of digital technologies, such as software applications, Internet infrastructure and advanced computers, to significantly improve existing or create new and innovative business processes [1].

In this paper, we analyze a simple and practical measurement framework for the digital economy, fundamentally based on input-output analysis [2], which uses available national accounts data. The framework is applied to 16 economies in Asia, Europe, North America and the Pacific, including Australia, to produce an assessment of the digital economy.

The proposed framework of the digital economy includes both a method of measuring the digital economy based on a value-added calculation.

According to Dynan and Sheiner, the use of the measurement method in the framework presents other accounts and the economy in the context of gross domestic product (GDP) [3].

The Organization for Economic Co-operation and Development (OECD) and the United States Bureau of Economic Analysis (USBEA) have similarly proposed a measurement method based on national accounts [4]. In particular, the OECD and USBEA propose an approach that uses a supply and use framework.

The former includes the entire value of transactions related to digital platforms, as well as the value of the platforms themselves, while the latter only calculates margin and broker fees on such transactions.

Meanwhile, Huawei and Oxford Economics (2017) used digital spillover effects to estimate the global digital economy, which they estimate to be $11.5 trillion [5].

Consider the core evaluative framework of the digital economy, which defines digital products as goods and services whose primary function is the generation, processing and/or storage of digital data [6].

The components of the digital economy measurement framework are: A country's digital economy1 based on proposed core digital products classification, Digital industry GDP, Digitally enabling industries' value-added to final digital products.

The digital GDP equation (GDP = gross domestic product) Inverse Leontief coefficients, show that the total output x of a standard input-output table (IOT) can be briefly represented as a Leontief function.

Gross outputs x in a standard input-output table (IOT) can be concisely represented as a function of the Leontief Inverse. A standard input-output table (IOT) is generally comprised of three quadrants (*Tbl. 1*).

Gross outputs x in a standard input-output table (IOT) can be concisely represented as a function of the Leontief Inverse, $(I - A)^{-1}$, and final demand, y. Equation (1) describes this relationship.

$$x = (1 - A)^{-1} y. \quad (1)$$

Further mathematical manipulations would also allow derivation of a similar equation for economy-wide GDK (8, p. 78–80). For brevity, let the Leontief inverse, $(1 - A)^{-2} B$. A direct value-added coefficient vector is defined as

$$K = (k_1 k_2 ... k_n) = \left(\frac{gka_1}{x_1} \frac{gka_2}{x_2} ... \frac{gka_n}{x_n} \right), \quad (2)$$

where $gka, j = 1, 2, ..., n$, refers to the gross value-added (GKA) generated by industry j and x_j refers to the gross output of the same industry j. Thus, each entry in K is the ratio of industry j's GKA to its own output. It is shown below that pre-multiplying K from Equation (2) to x from Equation (1) would yield an expression that calculates economy-wide GDK via the production approach (Equation (3)):

$$kx = vBy \rightarrow gka_1 + gka_2 + ... + gka_n = \\ = \sum_{i=1}^{n} \sum_{j=1}^{n} k_i b_{ij} y_j = economy - wide\, GDK. \quad (3)$$

The core digital economy equation (Equation (4)) is derived by consolidating Equation (4) with the value of the backward linkage of fixed capital goods con-

Table 1

Standard Industry Input-Output Table

	Intermediate consumption				Final demand	Gross output
	Industry 1	Industry 2	…	Industry *n*	Quadrant II: *y*	*X*
Industry 1	Quadrant I: z					
Industry 2						
…						
Industry *n*						
Value-added	Quadrant III: *gka*					
Gross output	x′					

sumed by the digital industry. In Equation (4) the "agg" subscripts are suppressed for notational simplicity:

$$GDK_{digital} = I^t (\ddot{K}_{agg} B_{agg} \dot{y}_{agg})^T \varepsilon_1 - \\ - [dig\,(\ddot{K}_{agg} B_{agg} \dot{y}_{agg})]^T \varepsilon_1. \quad (4)$$

Equation (5) captures all contemporaneous input-output transactions with respect to exogenous final demand.

$$GDK_{digital} = I^t \ddot{K}_{agg} B_{agg} \dot{y}_{agg}\, \varepsilon_1 + I^t (\ddot{K}_{agg} B_{agg} \dot{y}_{agg})^T \varepsilon_1 - \\ - [dig\,(\ddot{K}_{agg} B_{agg} \dot{y}_{agg})]^T \varepsilon_1 + (I - \varepsilon_1)^T K\; B_{agg}\; \dot{y}_{agg}\, \varepsilon_2; \quad (5) \\ GDK_{digital} = I^t \ddot{K}\, B\, \dot{y}\, \varepsilon_1 + I^t (\ddot{K}\, B\, \dot{y})^T \varepsilon_1 - [dig\,(\ddot{K}\, B\, \dot{y})]^T \varepsilon_1 + \\ + (I - \varepsilon_1)^T \ddot{K}\, B\, \dot{y}\, \ddot{r}\; \varepsilon_2.$$

The first term – $I^t \ddot{p}_{agg} B_{agg} \dot{y}_{agg} \varepsilon_1$ directly calculates the backward linkage related to the digital industry while the second term $I^t k\, \varepsilon_1$, – gives the forward linkage. To account for the double-counted term, the diagonal entry in the $\ddot{k}\, B\, \dot{y}$ matrix that corresponds to the digital industry is removed, which is why $[dig\,(\ddot{k}_{agg}\; B_{agg}\; \dot{y}_{agg})]^T \varepsilon_1$ is subtracted in GDK digital. An "eliminator vector" ε_1 is used to mathematically eliminate entries that should not be included in calculations.

The $n \times 1$ eliminator vector ε_2 is post-multiplied to $(I - \varepsilon_1)^T \ddot{k}\, B\, \dot{y}\, \ddot{r}$ to arrive at a value for the backward linkage of fixed capital goods consumed by the digital industry.

The main data sources of the Digital Economy Framework are the National Supply and Use Tables (SUT) and the IOT. SUT is the main basis for national economic accounting systems, as a data set that describes interactions in the economy and as a balance sheet framework for GDK calculations (UN 2022).

The IOT combines the identities in the supply table and the use table into a single identity (UN 2022). As discussed, the proposed framework methodology requires matrices and vectors directly extracted from IOTs. SUTs may be easily transformed into IOTs using a transformation model prescribed by Eurostat.

When measuring global value chains (GVCs) in the context of the digital economy, a reliable cross-economy IOT must be used. One useful resource for conducting such an analysis is the Multi-Regional Input-Output Tables (MRIOT) produced by the Asian Development Bank.

The MRIOT database contains information on the production, consumption and trade linkages of 62 economies and the total economy for the "rest of the world". Each economy has 35 sectors and five components of final demand. MRIOT generally follows the sources and methods used to create the World Input Output Database (WIOD) maintained by the University of Groningen.

The MRIOT sectors are: electrical and optical equipment (c14), post and telecommunications (c27) and machinery and equipment rental and other business activities (c30) comprise the digital sectors identified in the framework and therefore each is divided into two sub-sectors for isolation.

In the paper, we analyze the 38-sector survey of MRIOT for 2020–2022. The framework methodology summarized in Equation 6 is applied to 16 economies: Australia, Canada, Denmark, Fiji, Germany, India, Indonesia, Japan, Kazakhstan, Malaysia, People's Republic of China (PRK), Republic of Korea (ROK), Singapore, Taipei (China), Thailand, and the USA. These are the economies that belong to eight regions for which SUT or IOT is available: 11 of the 16 economies are within Asia and the Pacific (i. e. Central Asia, East Asia, South Asia, Southeast Asia and the Pacific) [7].

According to Barefoot et al., estimates from additional OECD member economies in Europe and North America, as well as Australia, were included to provide a more diverse set of economies and enrich further comparative analyses [8].

The preliminary estimates of GDP digital as a percentage of GDP, by economy, are summarized in *Fig. 1*. It can be observed that the size of the digital economy as a percentage of GDP ranges from 2% to 9% for all economies examined.

GDP for the 16 studied economies from 2010 to 2019, assessed across the four terms that make up the core digital economy equation (Equation (5)). Respectively, these terms represent the following in relation to an economy's digital sector: (i) its backward linkages,

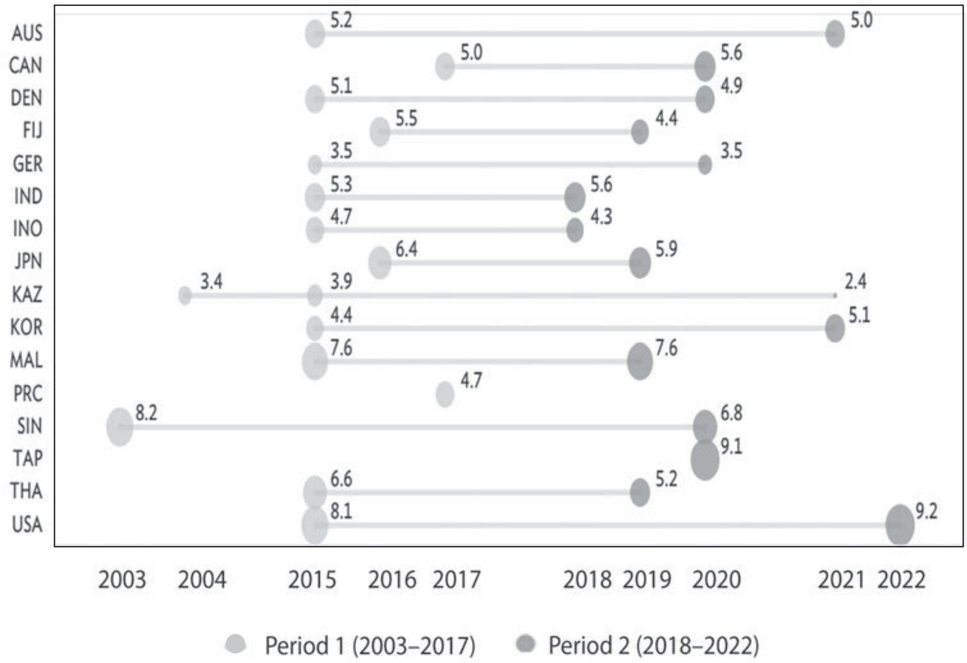

Fig. 1. Digital Economy as a Proportion of Total Economy (% of gross domestic product)

Note: AUS – Australia; CAN – Canada; DEN – Denmark; FIJ – Fiji; GER – Germany; IND – India; INO – Indonesia; JPN – Japan; KAZ – Kazakhstan; KOR – Republic of Korea; MAL – Malaysia; PRC – People's Republic of China; SIN – Singapore; TAP – Taipei, China; THA – Thailand; USA – United States.

Source: Calculations of the Digital Economy Measurement Framework study team, using input-output and related data from various national statistics offices and international databases.

A declining digital economy as a percentage of GDP is observed in all economies, except in Canada, India, the ROK, and the US and Malaysia. While measures of the digital economy as a percentage of GDP generally declined, or posted only marginal increases through the years, this does not imply a declining impact on, and relevance to, the global economy. Because the SUTs and national IOTs examined in this report are stated in current prices, the measures derived do not allow for changes in prices of the core digital products. Looking at digital consumer products, there is no question that their prices have significantly declined over the past 2 decades. In the US alone—one of the world leaders in consumer electronics (Statista 2020) – the producer price index (PPI) of portable computers, laptops, tablets, and other single-user computers has fallen from a PPI of 804.9 in 2000 to a PPI of 15.6 in 2020 (USBLS 2021), a decline of approximately 98% [9].

Drivers of the digital economy can more richly be analyzed in terms of forward and backward linkages. *Fig. 2* shows the disaggregation of digital economy (ii) its forward linkages, (iii) the double-counted term (i. e., the digital sector's value-added contribution to its own final products), and (iv) the nondigital products it capitalizes.

As Fig. 2 shows, a major proportion of the digital GDP of Australia, Denmark, Fiji, and Germany can be attributed to forward linkages (second term – green bars), accounting for more than 40% of each economy's digital GDP. This means that, in these economies, the digital sector more prominently acts as a supplier of value-added to domestic nondigital sectors. For example, Germany has developed a comparative advantage in global ICT services, supplying key service inputs, such as IoT components, to automotive industries (UNCTAD 2019). Comparing these economies with Taipei, China; Thailand; and the PRC, the latter economies have a greater fraction (above 40%) of their digital GDP contributed by backward linkages (first term – dark blue bars). In these economies, the digital sector is more notably a user of value-added from domestic nondigital sectors. This is attributable to the presence of major computer brands in these economies, which

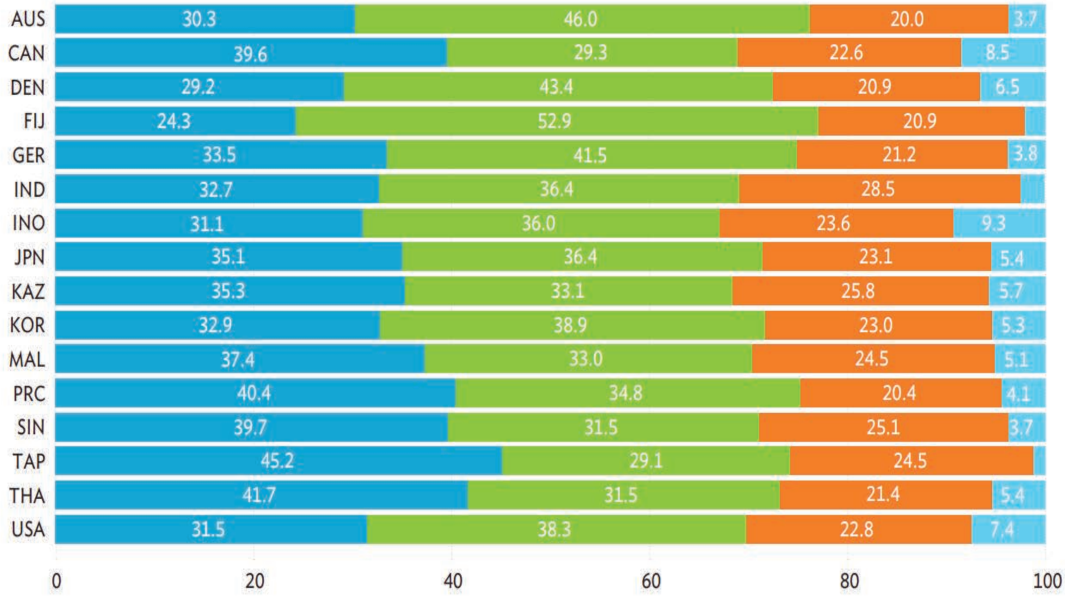

Fig. 2. Disaggregation of the Digital Economy by Terms of Equation (5)

naturally require various parts and components from different suppliers in the production chain [10].

Across all individual economies, the double-counted term or the contribution of the digital sector to itself (third term – orange bars) comprises around 20% to 29% of the digital GDP of all economies. This suggests that the reliance of the aggregate digital sector on itself is of nearly equal weight across all economies examined. Dependence on non-digital gross fixed capital formation or GFCF (fourth term – light blue bars) appears to be the smallest share for all economies' digital GDP, with the largest shares observed for Indonesia at 9.3% and Canada at 8.5%. The earlier calculations of the CAGR of the whole digital economy are augmented by the CAGR of the disaggregated digital GDP.

Fig. 3 shows the CAGR (Compound Annual Growth Rates) of each term comprising digital GDP expressed as a percentage of economy-wide GDP.

The chart reveals that the largest changes were dealt by the GFCF from nondigital sectors (fourth term – light blue bars) in a majority of the studied economies. Fiji's fourth term changed by –44.2% annually (and –42.5% when expressed in local currency value), indicating that its purchase of nondigital GFCF decreases at a rate significantly higher than any other economy's. This can be explained by a large decrease in construction GFCF purchased by digital industries, FJ$326,330 in 2017 compared to FJ$22,486,237 in 2011 (FBS 2018, 2022). The inverse is true for economies such as Canada, Germany, and Singapore, for which nondigital GFCF is increasingly purchased by digital industries.

CONCLUSIONS

Using national accounts data from 16 economies in different regions of the world, the results are clear. Despite the narrow definition adopted in the framework, the digital economy accounts for a significant part of the GDP of all sampled economies (approximately 2% to 9%). However, characterizing the role of the digital economy.

Varies in different economies – some act more as value-added providers in the economy, while others act as consumers.

As digital technologies play different roles in non-digital products, measuring the digitally dependent economy allows for a more comprehensive understanding of the digital economy in general.

Therefore, economies with high imports of digital products, as well as economies with industries that depend heavily on core digital sectors, are likely to have smaller digital economy estimates than others. ■

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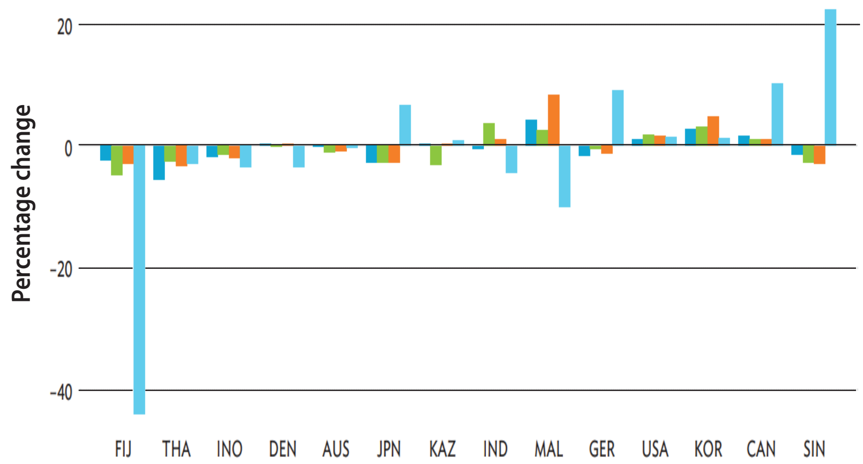

Fig. 3. Compound Annual Growth Rates of Normalized Digital Gross Domestic Product (disaggregated by term)

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