

Karymshakov, Kamalbek; Azhgaliyeva, Dina; Mishra, Ranjeeta; Aseinov, Dastan

**Working Paper**

## Evaluating Covid-19's impact on firm performance in the carec region using night-time light data: Azerbaijan, Georgia, Kazakhstan, and Mongolia

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## **ADB Working Paper Series**

### **EVALUATING COVID-19'S IMPACT ON FIRM PERFORMANCE IN THE CAREC REGION USING NIGHT-TIME LIGHT DATA: AZERBAIJAN, GEORGIA, KAZAKHSTAN, AND MONGOLIA**

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Kamalbek Karymshakov, Dina Azhgaliyeva,  
Ranjeeta Mishra, and Dastan Aseinov

No. 1332  
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Kamalbek Karymshakov is vice rector at Kyrgyz-Turkish Manas University, Bishkek, Kyrgyz Republic. Dina Azhgaliyeva is a research fellow at the Asian Development Bank Institute, Tokyo, Japan. Ranjeeta Mishra is a consultant at the Reserve Bank of India. Dastan Aseinov is an assistant professor at Kyrgyz-Turkish Manas University.

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Please contact the authors for information about this paper.

Email: [kamalbek.karymshakov@manas.edu.kg](mailto:kamalbek.karymshakov@manas.edu.kg)

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Asian Development Bank Institute  
Kasumigaseki Building, 8th Floor  
3-2-5 Kasumigaseki, Chiyoda-ku  
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500  
Fax: +81-3-3593-5571  
URL: [www.adbi.org](http://www.adbi.org)  
E-mail: [info@adbi.org](mailto:info@adbi.org)

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**Abstract**

This study examines economic activity measured with firm performance indicators using the changes in intensity of night-time light in four CAREC economies: Azerbaijan, Georgia, Kazakhstan, and Mongolia. The empirical analysis is based on the World Bank Enterprise Survey (WBES) data for 2019 and a follow-up survey conducted during the COVID-19 pandemic. The Enterprise Survey dataset was enhanced with data on night-time light intensity from Google Earth and the strictness of “lockdown-style” policies, i.e., the stringency index from Hale et al. (2021). Using the probit regression model, this study investigates the impact of COVID-19 on firm performance and night-time light in CAREC countries. Firm performance is measured using four variables: decrease in sales, demand, export share, and working hours. Our results show that, as the night-time light increases, the likelihood of performance deterioration is reduced. Larger firms are more likely to maintain their performance than smaller firms. The sales in the manufacturing, clothing, and services sectors are more likely to decline than those in the food sector. Accordingly, the results point to a significant decline in the performance of firms operating in the service sector compared with those in the food sector during the pandemic.

**Keywords:** Central Asia, COVID-19, big data, firm performance, gender, SMEs

**JEL Classification:** C55, L25, C13, C25

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# 1. INTRODUCTION

One of the main advantages of remote sensing data for economic analysis is the opportunity to analyze the intensity of economic activity when information is difficult to obtain (Henderson, Storeygard, and Weil 2012; Donaldson and Storeygard 2016). Lan et al. (2021) argued that, in the case of the People's Republic of China, change in the intensity of night-time light is correlated with people's activities and government prevention measures, meaning that night-time light data can be used to monitor changes in human behavior during restrictions. Analogously, Beyer, Jain, and Sinha (2021) indicated that the divergence of night-time light intensity from that during the relative pre-COVID-19 months in India is positively associated with restrictions in districts. Roberts (2021) showed that changes in night-time light in Morocco explain the drop in economic activity measured as changes in the real GDP during the COVID-19 pandemic.

Although there is a large consensus on the use of night-time light intensity to track changes in economic activity, night-time light might itself be subject to energy demand and consumption behavior changes caused by COVID-19. Overall, the restrictions on mobility because of COVID-19 caused a decrease in energy consumption.<sup>1</sup> However, along with the decreased consumption, there were substantial spatial and temporal differences (Jiang, Van Fan, and Klemeš 2021). The increased time spent at home during the pandemic and the transition to remote work may have affected building energy consumption (Rouleau and Gosselin 2021; Tleuken et al. 2021). This may not necessarily imply low intensity of night-time light. Therefore, along with the general expectation that night-time light may help to understand private sector performance during the pandemic, the energy consumption behavior during the restrictions may create some vague perspectives on the ability to explore economic activity with night-time light data.

The Central Asia region has recorded impressive economic growth rates since 2000, driven mainly by the exporting of commodities. Small and medium-sized enterprises play an important role in these economies, on which COVID-19 has had a severe negative impact. However, under the conditions of unavailability of regional income estimates in high-frequency periods, night-time light could serve as a useful proxy indicator for measuring economic activity at the national/sub-national level, especially in countries with low statistical capacity.

The CAREC region, which extends from Azerbaijan to the People's Republic of China (PRC), is an increasingly important channel for international trade and energy resources. The COVID-19 pandemic and subsequent economic crisis have brought unprecedented challenges to the CAREC region. The COVID-19 crisis has led to a reduction in demand and supply due to both uncertainty and policy interventions, such as lockdowns, social distancing, and travel restrictions, which are having a severe impact on CAREC countries (Azhgaliyeva et al. 2022). Aseinov et al. (2022) provided empirical evidence from Azerbaijan, Georgia, Kazakhstan, and Mongolia showing how different factors, including firm characteristics and government policy, affect the probability that a firm will adjust its activities to COVID-19. The results indicate that the firms that adapted to the COVID-19 crisis are younger foreign firms that have been innovative in the recent past, with female managers, a formal firm strategy with key performance indicators, and their own website. Li et al. (2017) showed that night-time

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<sup>1</sup> <https://www.iea.org/reports/covid-19-impact-on-electricity>.

light satellite images are an effective tool for monitoring spatial and temporal social economic parameters in Central Asia.

Empirical studies on the impact of COVID-19 on firm performance in the CAREC region are limited. This paper contributes to the literature by studying this topic, controlling for regional economic activity, using night-time light data.

This study aims to examine the change in firm performance as a factor of the change in intensity of night-time light, COVID-19-related restrictions, and other microeconomic attributes in four CAREC economies: Azerbaijan, Georgia, Kazakhstan, and Mongolia. The empirical analysis is based on the World Bank Enterprise Survey (WBES) data for 2019 and the follow-up survey performed during the COVID-19 pandemic. The Enterprise Survey dataset is enhanced with data on night-time light intensity from Google Earth, COVID-19, and the strictness of “lockdown-style” policies, i.e., the stringency index (Hale et al. 2021). The main contribution of this paper to the existing literature is that it uses night-time light data to study firm performance in the CAREC region.

The paper is structured as follows. The next section describes COVID-19’s dynamics in the four economies. Sections 3 and 4 discuss the data sources and methodology, respectively. Section 5 presents the estimation results. Section 6 concludes and provides policy recommendations.

## **2. COVID-19 DYNAMICS IN CENTRAL ASIA**

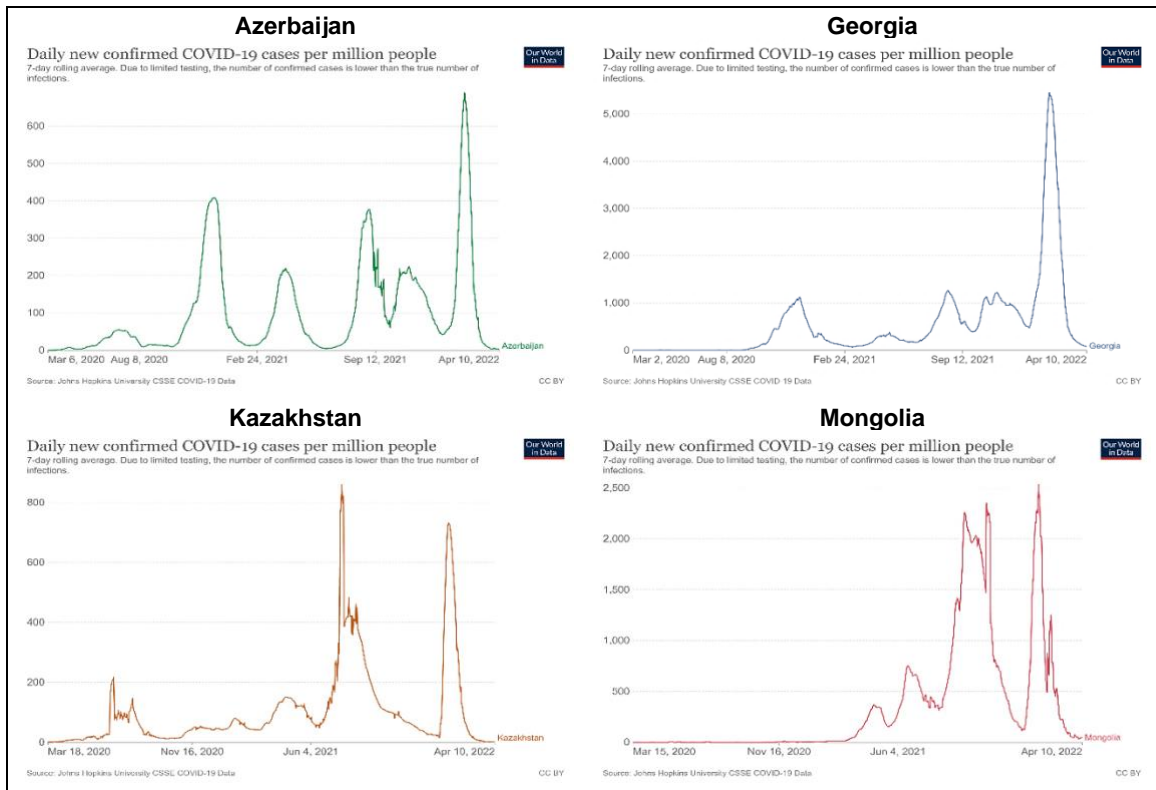
COVID-19 severely affected the CAREC region. Cases of COVID-19 were high in summer 2021 in the four countries. Figure 1 illustrates the daily new confirmed COVID-19 cases per million people in the four countries with a 7-day rolling average. Due to limited testing, the number of confirmed cases could be lower than the true number of infections.

The daily new confirmed COVID-19 deaths per million people are illustrated in Figure 2 using a 7-day rolling average. Due to varying protocols and challenges in the attribution of the cause of death, the number of confirmed deaths may not accurately represent the true number of deaths caused by COVID-19.

The strictness of the “lockdown-style” policies that primarily restricted people’s behavior, according to the COVID-19: stringency index, is provided in Figure 3. The stringency is measured from 0 (least strict restrictions) to 100 (strictest restrictions). The stringency index records the number and strictness of government policies. It does not measure the appropriateness or effectiveness of a response to the COVID-19 pandemic. The strictness of lockdown policies was at its highest in the first half of 2020 and gradually declined due to the spread of vaccination.

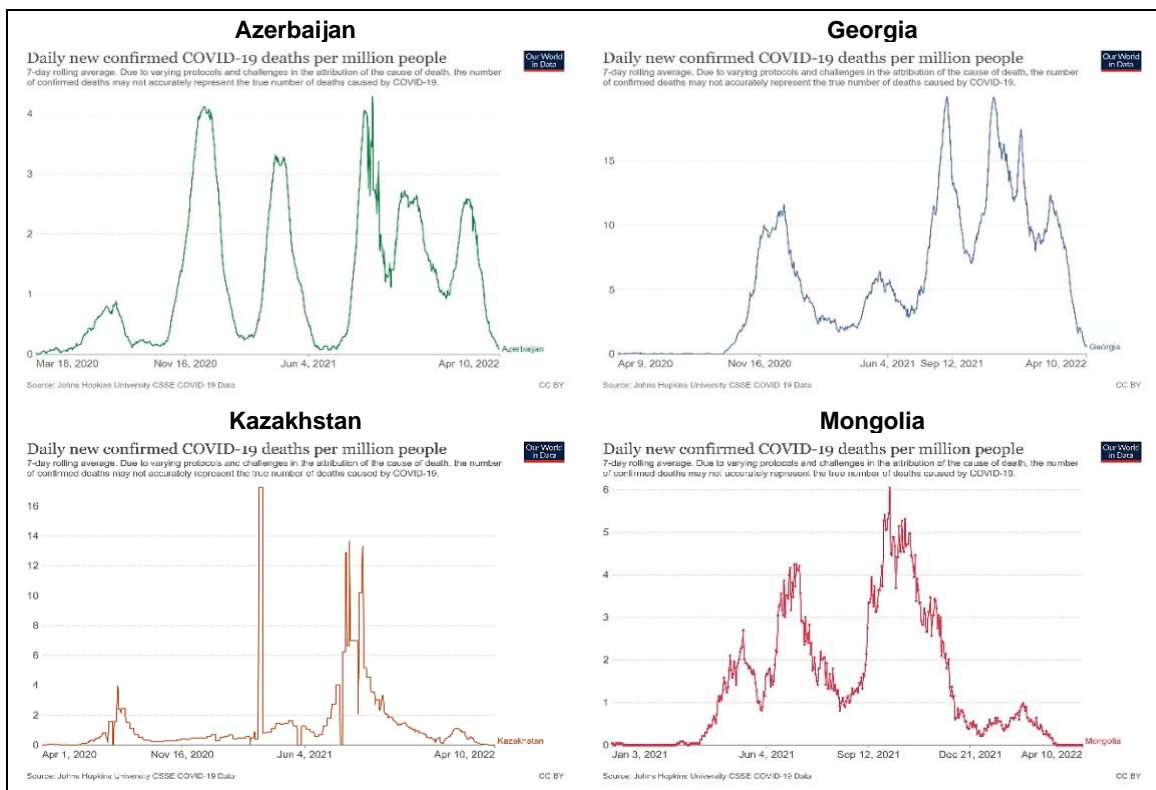
The daily share of the population receiving a COVID-19 vaccine dose is presented in Figure 4 and Figure 5. Figure 4 illustrates the 7-day rolling average of all doses, including boosters, which are counted individually, as a share of the population. Figure 5 shows that, in Mongolia, the majority of the population received a COVID-19 vaccination in the middle and at the end of 2021.

Figure 1: COVID-19 Cases



Source: Our World in Data.

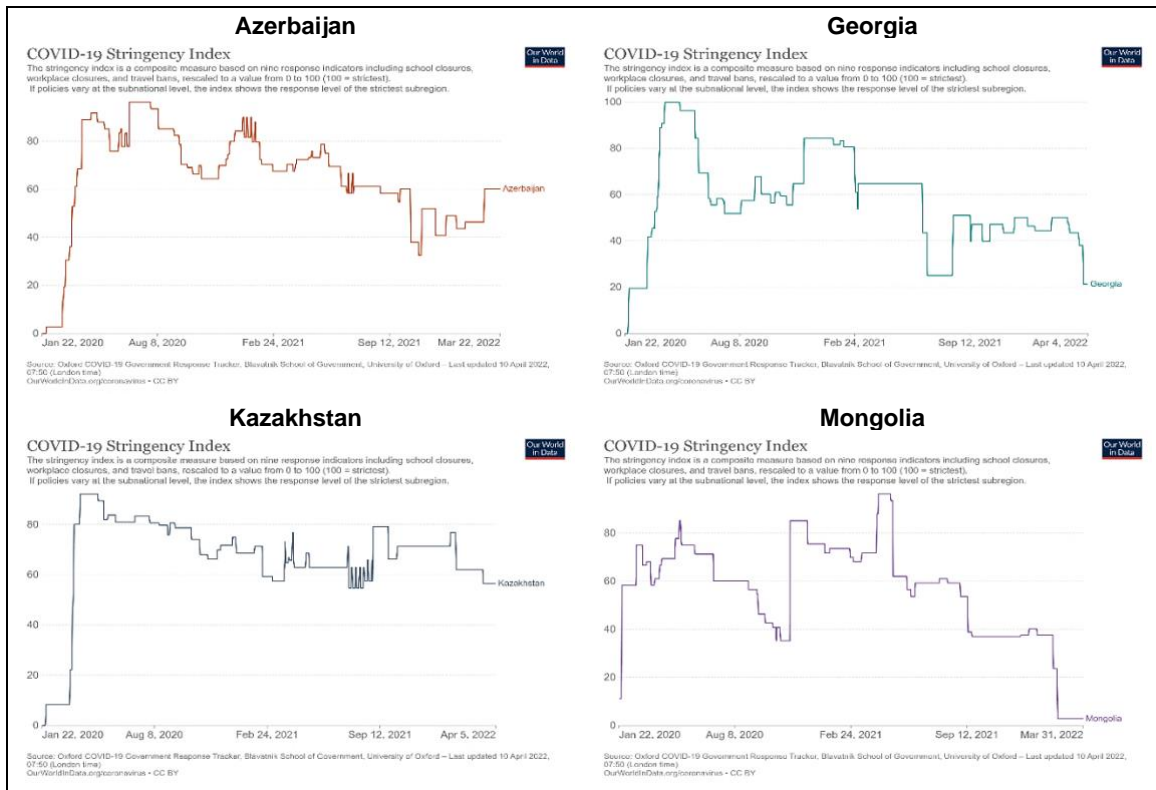
Figure 2: COVID-19 Deaths



Source: Our World in Data.

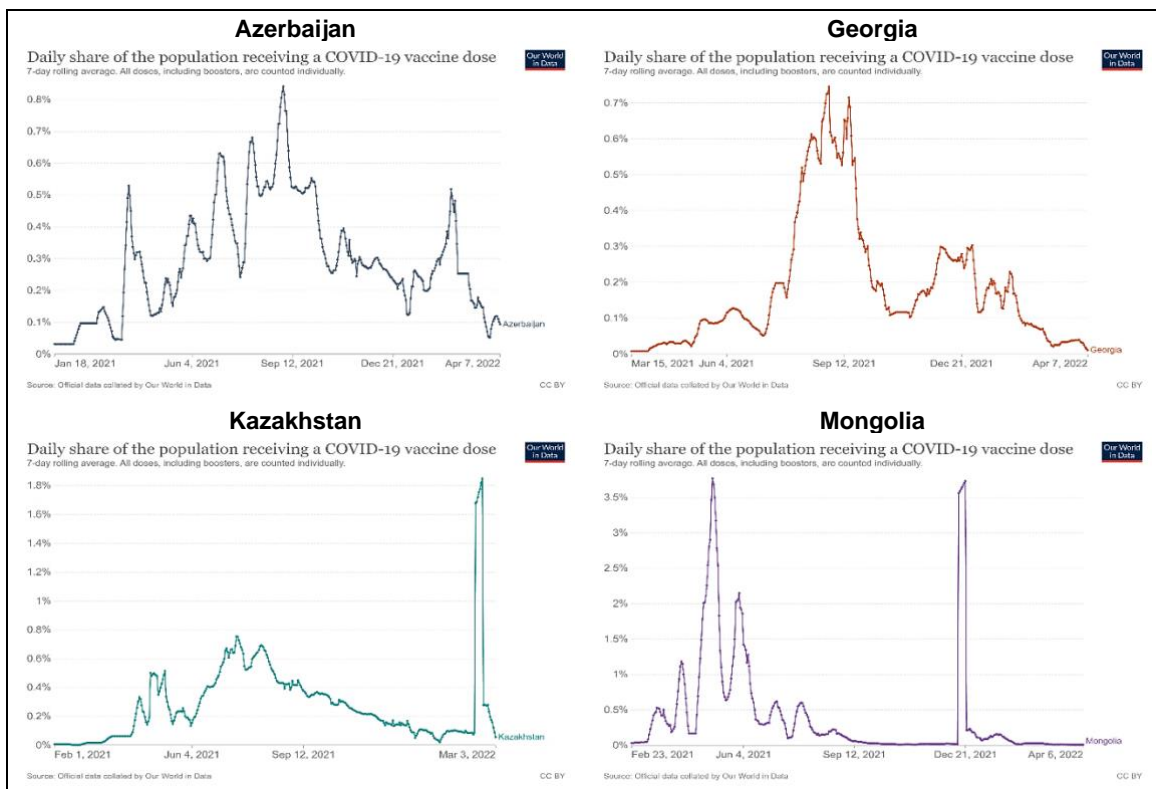


Figure 3: Stringency Index



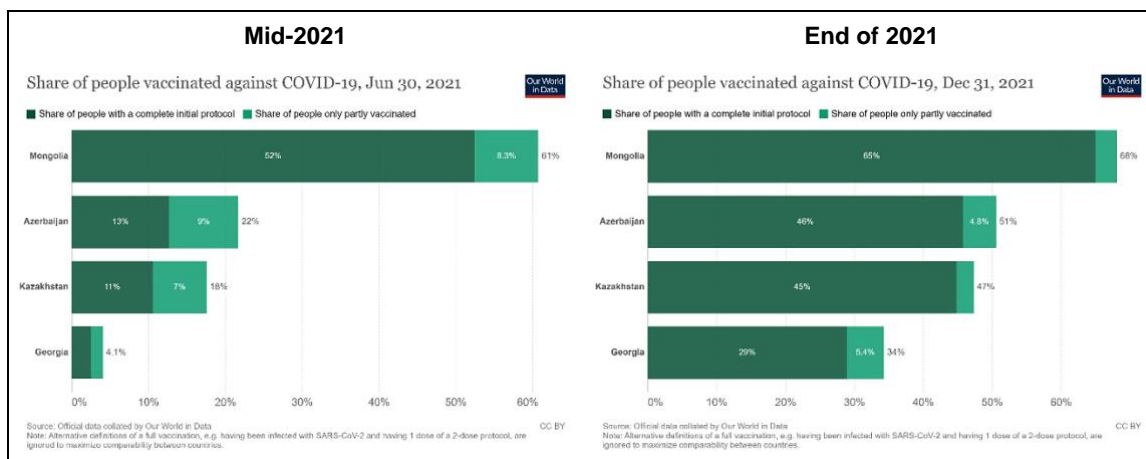
Source: Our World in Data.

Figure 4: Population Receiving a COVID-19 Vaccine Dose



Source: Our World in Data.

**Figure 5: COVID-19 Vaccination in the Middle and at the End of 2021**



Source: Our World in Data.

### 3. DATA

#### 3.1 Data Source

The main dataset employed in our study consists of firm-level survey data for four CAREC countries. The World Bank (2022) Enterprise Survey, conducted before the COVID-19 pandemic and considered as the baseline survey, and the follow-up surveys, carried out during the COVID-19 pandemic, are combined to obtain data on the performance and characteristics of firms in the CAREC countries. The baseline survey, conducted in the pre-pandemic period, focused on the business environment as well as the key characteristics and performance of firms. The follow-up surveys, conducted during the pandemic, essentially asked questions about the impact of COVID-19 on business operations and the behavior of firms during the pandemic.

After deleting responses with missing values, the total sample consists of 2,816 observations. The sample distribution by country for both baseline and follow-up surveys is presented in Table 1. Due to the lack of availability of follow-up survey data, our dataset covers only four CAREC countries. The dataset contains two waves of the follow-up surveys each for Georgia and Mongolia and one wave each for Azerbaijan and Kazakhstan.

**Table 1: Dataset: Survey Dates and Waves**

Country	Baseline Survey		Follow-Up Survey				Number of Observed Firms
	Date	N	Wave I		Wave II		
			Date	N	Date	N	
Azerbaijan	July–Dec 2019	72	Apr, May 2021		105		105
	Jan–Feb 2020	33					
Georgia	Jan 2020	14	June 2020	614	Oct, Nov 2020	589	659
	Mar–Nov 2019	1187					
Kazakhstan	Jan–Oct 2019	871	Jan–May 2021		871		871
Mongolia	Dec 2018	19					
	Jan–June 2019	618	Aug. 2020	314	Feb 2021	323	329
<b>Total</b>		<b>2,814</b>		<b>1,904</b>		<b>912</b>	<b>1,964</b>

Note: N denotes the number of observations.

Source: Own elaboration using data from the World Bank (2022).

The baseline survey covers the period from December 2018 to February 2020, that is, the pre-pandemic period, while the follow-up surveys are from the pandemic period. As can be seen from the table, about 37% of the follow-up surveys are performed during the period of severe restrictions and intensive spread of coronavirus in the countries under consideration, specifically from April to August 2020. The remaining follow-up surveys cover the period from October 2020 to May 2021. The dataset is supplemented with other variables of interest, the monthly night-time illumination and hardness index, according to the WBES interview date (month and year) of the corresponding survey, country, and region/province.

The World Bank's (2022) Enterprise Survey claims to contain a representative sample of an economy's private sector: "a sample representative of the non-agricultural, non-extractive formal private economy."<sup>2</sup> The follow-up surveys follow firms included in the standard enterprise survey, which is the baseline survey in our case. Therefore, we assume that the dataset that we use for our estimations is representative (details on sample distributions are provided in Appendix Figures 1A–4A).

### 3.2 Summary Statistics

Table 2 reports the mean values of the variables used in the analysis. As can be seen from Table 2 and Figure 6, 70%, 60%, 51%, and 48% of the firms surveyed during the pandemic reported a decrease in their sales, the demand for their products and services, the total number of hours worked, and the share of exports in total sales, respectively. It should be noted here that the reduction in the share of exports in the follow-up data is only available for the first wave for Georgia and Mongolia. The proportion of firms that experienced sales declines is larger in the second wave of the follow-up survey than in the first wave. In terms of country differences, the performance of the surveyed firms in Kazakhstan is less affected by the pandemic than that of the firms in Georgia and Azerbaijan.

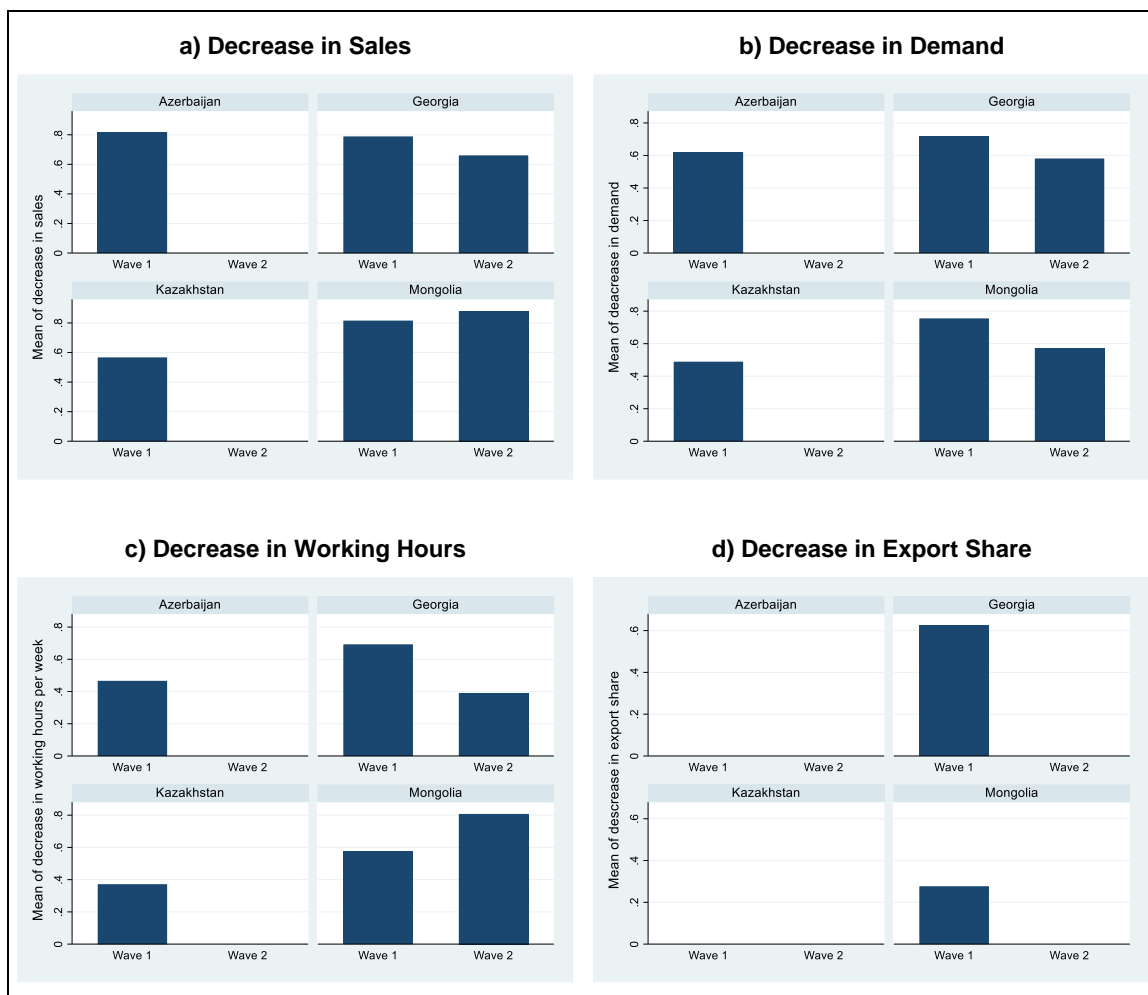
**Table 2: Descriptive Statistics**

Variables	Total Sample	Baseline Survey	Wave 1	Wave 2	Azerbaijan	Kazakhstan	Georgia	Mongolia
Sales (1=decrease)	0.70		0.69	0.72	0.81	0.57	0.72	0.84
Demand (1=decrease)	0.60		0.61	0.58	0.62	0.49	0.65	0.67
Worked hours (1=decrease)	0.51		0.51	0.51	0.47	0.37	0.54	0.68
Export share (1=decrease)			0.48				0.62	0.28
Night-time light (1=increase)	0.8718	0.872	0.871	0.873	0.96	0.94	0.75	1.00
Stringency index (100=strictest)	60.06		60.94	58.23	67.42	64.60	56.08	60.17
Competition (N)		445.70	460.80	414.70	371.50	513.30	585.60	117.80
Online business activity (1=firm has started or increased)	0.25		0.28	0.18	0.58	0.31	0.17	0.29
KPI (1=firm has key performance indicators)		0.37			0.64	0.46	0.22	0.43
Foreign ownership (%)		5.16			5.75	2.50	8.13	3.03
Female ownership (1=yes)		0.33			0.08	0.33	0.29	0.46
Gender of manager (1=female)		0.27			0.12	0.26	0.22	0.42
Industry (N)		2,812			105	871	1,199	637
<i>Food</i>		398				138	260	
<i>Retail</i>		570			34	104	237	195
<i>Manufacturing, Garments</i>		720			31	222	257	210
<i>Metal, Machinery, and Equip.</i>		223				223		
<i>Mineral</i>								
<i>Services</i>		901			40	184	445	232
Firm size (N)		2,812			101	871	1,203	637
<i>Micro</i>		164				2	148	14
<i>Small</i>		1,366			46	450	544	326
<i>Medium</i>		890			37	286	374	193
<i>Large</i>		392			18	133	137	104

Source: Hale et al. (2021); World Bank (2022); and Google Earth.

<sup>2</sup> [https://www.enterprisesurveys.org/content/dam/enterprisesurveys/documents/methodology/Sampling\\_Note-Consolidated-2-16-22.pdf](https://www.enterprisesurveys.org/content/dam/enterprisesurveys/documents/methodology/Sampling_Note-Consolidated-2-16-22.pdf).

**Figure 6: Decrease in Sales, Demand, Working Hours, and Export Share (Wave 1 and Wave 2)**



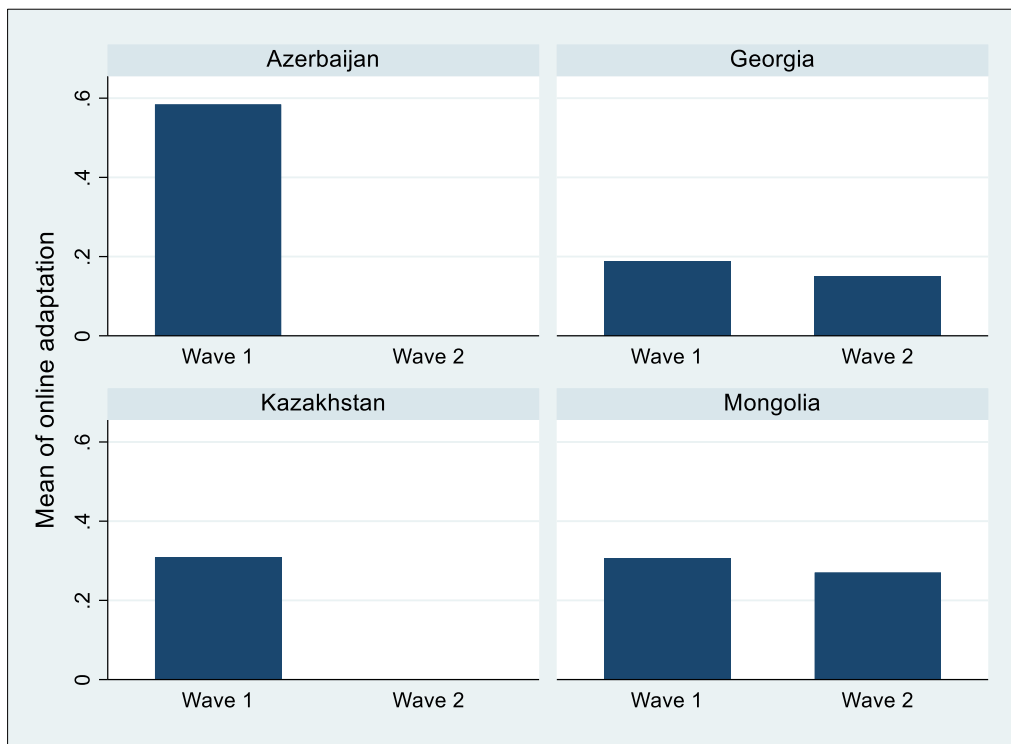
Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan. The decrease in export share is only available from Georgia and Mongolia for wave 1.

Source: Own elaboration using data from the World Bank (2022).

The differences in the averages between waves indicate that the pandemic-related restrictions, the number of competitors, and the number of firms that started or increased their online activity declined slightly during the second wave compared with the first wave in Georgia and Mongolia (Figure 7). A relatively large proportion of firms in Azerbaijan had key performance indicators and moved their activities online (nearly 60% of firms). However, it should be noted here that the number of firms observed is much smaller than that in other countries.

The average share of foreign ownership is generally low in Azerbaijan, Georgia, Kazakhstan, and Mongolia (Figure 8). The average share of foreign ownership is below 10% in all four countries. As regards the participation of foreign capital in ownership and the level of competition, Georgian firms are in the lead (Figure 8). A slight reduction in the average share of foreign ownership in wave 2 compared with wave 1 in Georgia and Mongolia is also observable.

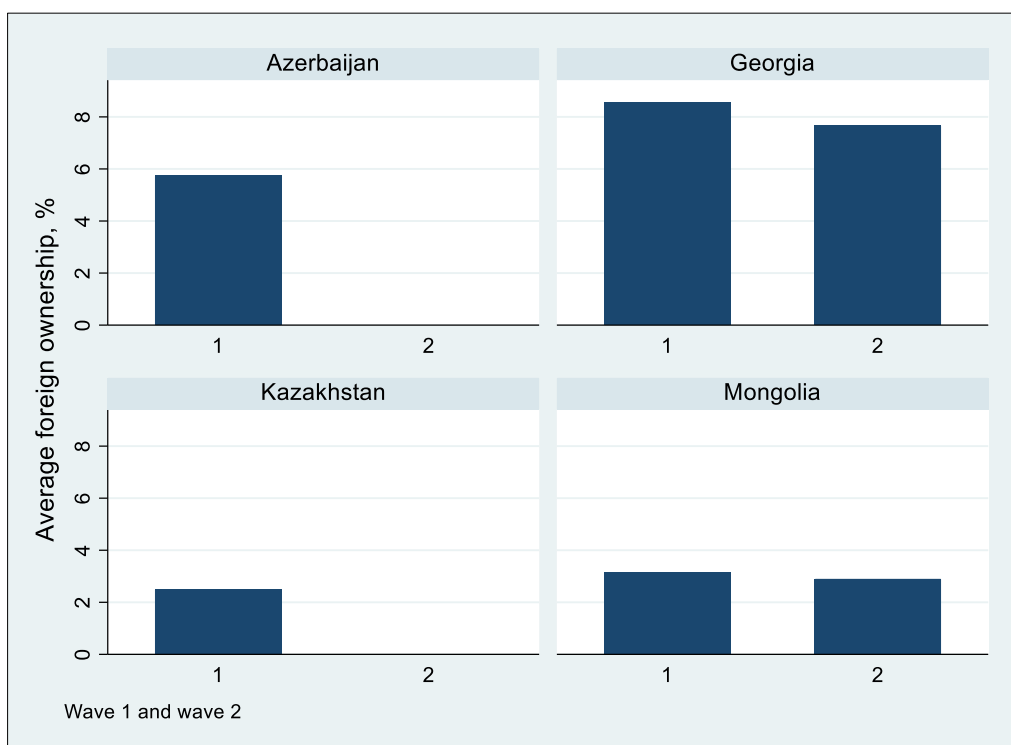
**Figure 7: Average Online Business Activity (Wave 1 and Wave 2)**



Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan.

Source: Own elaboration using data from the World Bank (2022).

**Figure 8: Average Foreign Ownership (Wave 1 and Wave 2)**

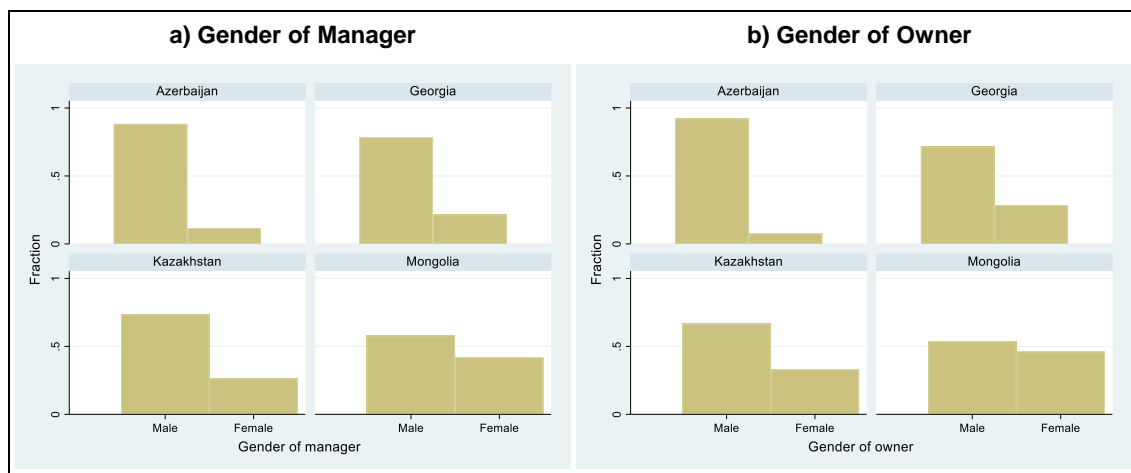


Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan.

Source: Own elaboration using data from the World Bank (2022).

On average, most firm owners and managers in Azerbaijan, Georgia, Kazakhstan, and Mongolia are male (Table 2 and Figure 9). The gender gap of firm owners and managers is notably large in Azerbaijan, Georgia, and Kazakhstan (in descending order). Table 2 and Figure 9 present noteworthy patterns of women's ownership and management among Mongolian firms. Women's participation in ownership and female top managers can be observed in 46% and 42% of Mongolian firms, respectively. The smallest gender gap of firm owners and managers among the four countries is in Mongolia.

**Figure 9: Gender of Firm Managers and Owners**

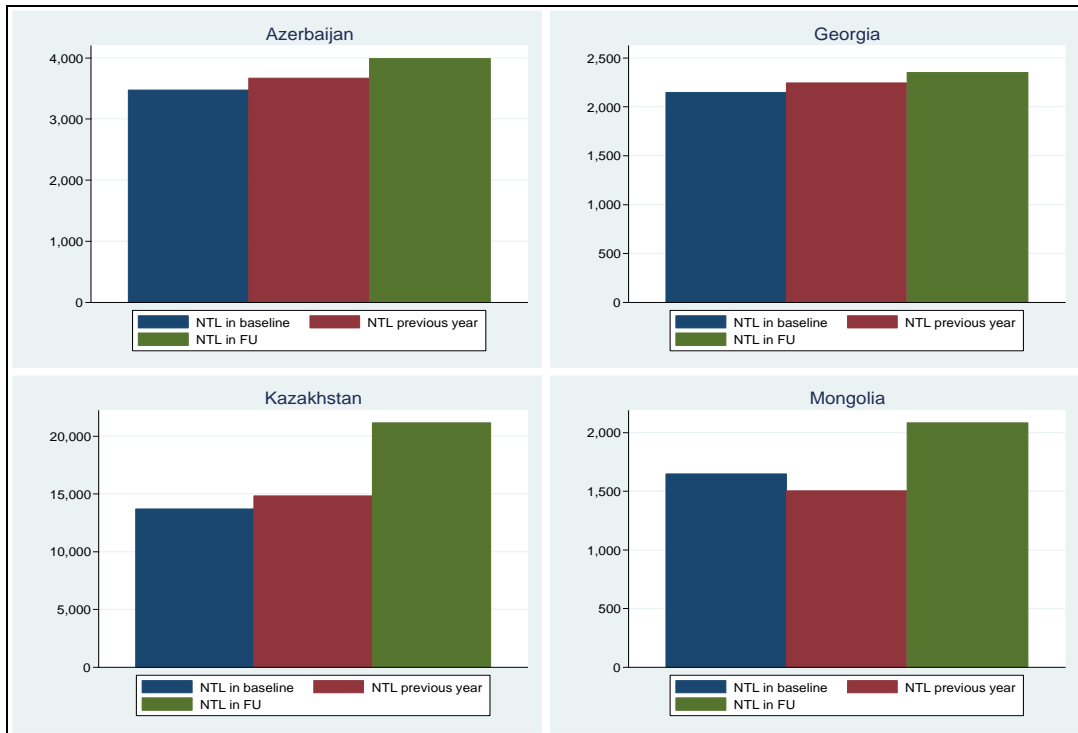


Source: Own elaboration using data from the World Bank (2022).

Night-time light data can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander 2015; Kabanda 2022). We use the data from Google Earth on night-time light (NTL) intensity.<sup>3</sup> NTL data are collected on a regional basis for each country and matched with the business survey dataset based on regions. Figure 10 shows the average night-time light (NTL) for CAREC countries during the three survey periods. First, it refers to the average month in which the baseline interview was conducted. Second, the previous-year NTL corresponds to the same month of the previous year in relation to the month of the subsequent survey. The third average refers to the month of the follow-up examination. Night-time light increased on average at a greater rate in Kazakhstan and Mongolia than in Azerbaijan and Georgia (Figure 10). It is very interesting that NTL increased during the COVID-19 pandemic in Azerbaijan, Georgia, Kazakhstan, and Mongolia because it is believed that, during COVID-19, NTL generally decreased due to lockdowns or did not increase (Beyer, Franco-Bedoya, and Galdo 2021; Xu et al. 2021). Since human activities and economic growth decreased during the COVID-19 pandemic due to lockdowns, the increase in NTL in Azerbaijan, Georgia, Kazakhstan, and Mongolia could be explained by improvements in access to infrastructure and urbanization. NTL varies substantially between capital cities and other regions. The growth of NTL is particularly noticeable in the capital city of Kazakhstan, Nur-Sultan (Figure 11). This could be due to urbanization and infrastructure construction.

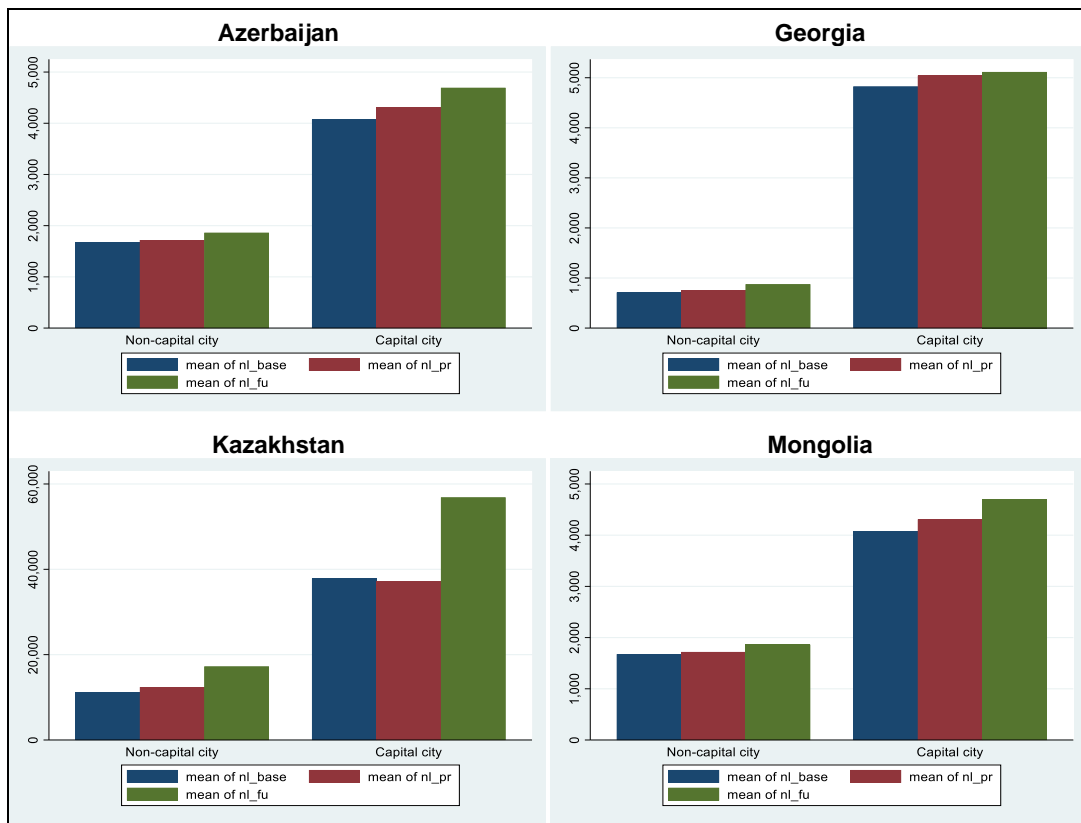
<sup>3</sup> VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1, which consists of monthly average radiance composite images using night-time data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB) ([https://developers.google.com/earth-engine/datasets/catalog/NOAA\\_VIIRS\\_DNB\\_MONTHLY\\_V1\\_VCMSLCFG](https://developers.google.com/earth-engine/datasets/catalog/NOAA_VIIRS_DNB_MONTHLY_V1_VCMSLCFG)).

**Figure 10: Average Night-Time Light (NTL)**



Source: Own elaboration using data from Google Earth.

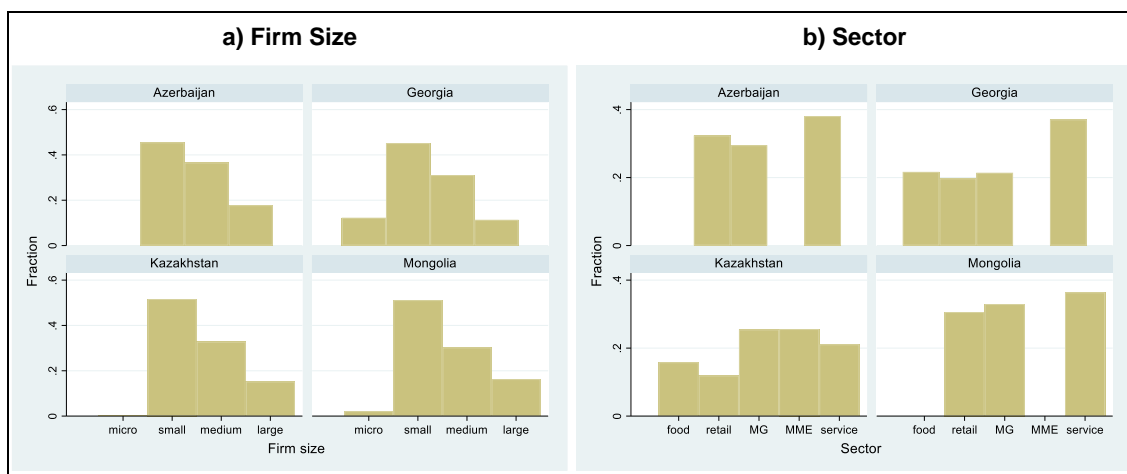
**Figure 11: Average NTL in the Capital City and Other Regions**



Source: Own elaboration using data from Google Earth.

The sample includes mainly (around 80%) small and medium-sized enterprises in all four countries (Figure 12a). The remaining 20% consists of micro and large enterprises. The sample contains enterprises across five sectors: (1) food; (2) retail; (3) manufacturing and garments (MG); (4) metal, machinery, and equipment (MME); and (5) services. The share of firms across sectors varies across countries (Figure 12b).

**Figure 12: Firm Sizes and Sectors**



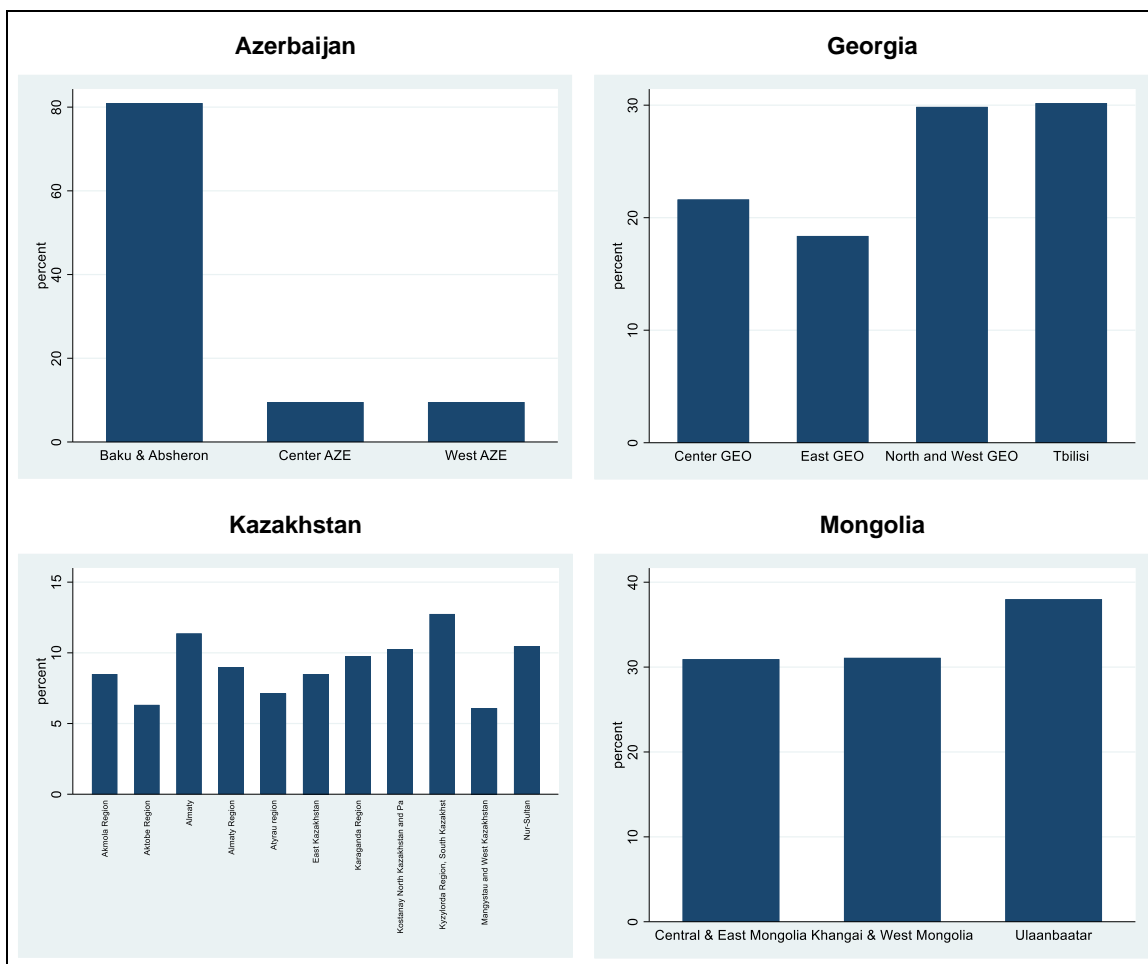
Note: (1) Food; (2) retail; (3) manufacturing and garments (MG); (4) metal, machinery, and equipment (MME); and (5) services.

Source: Own elaboration using data from the World Bank (2022).

The distribution of firms across regions/provinces (“oblasts”) is provided in Figure 13. Most of the firms in the sample from Azerbaijan (80%) are from Baku (the capital city) and Absheron. In the other three countries, the sample firms are more equally distributed across regions.



Figure 13: Distribution of the Sample across Regions<sup>a</sup>



<sup>a</sup> The capital cities are Nur-Sultan in Kazakhstan; Tbilisi in Georgia; Ulaanbaatar in Mongolia; and Baku in Azerbaijan. Source: Own elaboration using data from the World Bank (2022).

#### 4. METHODOLOGY

This study investigates the impact of COVID-19 on firm performance and night-time light in CAREC countries. The dependent variables used in our empirical models are measures of firm performance. These are dummy variables that take the value of 1 if a considered performance indicator has deteriorated and 0 if it has not. In such cases, a binary response probit regression model has generally been suggested as the appropriate specification (Horowitz and Savin 2001). Hence, this study employs the following probit regression model:

$$P(y_i = 1|x_i) = F(\beta_0 + \beta_k x_k) \tag{1}$$

where  $y_i$  is a dummy dependent variable indicating whether the firm performance measure has decreased. This specification considers the impact of the explanatory variables on the likelihood of a decrease rather than an increase in firm performance since firms' performance is likely to have declined due to the deteriorating business environment during the pandemic. In this context, the sales, demand, working hours, and share of exports in sales are defined as measures of firm performance. Hence, decreases in the sales, demand, working hours, and share of exports in sales in the

last complete month compared with the relative month in 2019 are considered as outcome variables in our model specifications.

$x_k$  is a vector of firm-specific and exogenous factors that influence firm performance.  $F(\cdot)$  is the cumulative density function of the error term, which is standard normally distributed and evaluated at given values of the independent variables (Long and Freese 2014). The covariates controlled in the models are firm characteristic and environmental variables.

In this study, it is assumed that firm characteristics, such as ownership and management, size, industry, performance targets, and the ability of a firm to transform its operations online during the pandemic, have affected firms' performance. To control for the diversity of impacts of the participation of women in management and ownership, we include dummies indicating whether the top manager is female and whether there is a woman among the owners. A variable measuring foreign capital participation as a percentage is also included to control for differences in the impacts of domestic and foreign capital on firm performance. Other firm-specific dummies are the size of the firm and its ability to move its business online. We control for firm size as the COVID-19 crisis may affect larger firms differently from smaller firms. Moving their business operations online could allow firms to be less affected by COVID-19-related restrictions and to maintain or even increase their performance. The use of key performance indicators (KPIs) is to help managers obtain information about whether the organization is performing properly and then take appropriate actions to achieve better performance indicators (Nastasia and Mironeasa 2016; Pîrlog and Balint 2016). Differences between firms in terms of the availability of key performance indicators (KPI) are controlled by a dummy variable that is 1 if a firm has a formally documented business strategy with clear key performance indicators and 0 otherwise.

The competition in the main market, industry, and the strictness index reflecting the impact of pandemic-related restrictions are also included in the models as factors that are likely to influence the environment in which a firm operates. During the COVID-19 recession, some industries were hit harder than those dependent on the movement of information. Those industries that depend on face-to-face communication and cannot interact remotely suffered dramatically. To control for this, we include industry dummies in our models. We use the number of competitors that a firm faced in the main market in which it sells its main product to account for competition. A more convenient and briefer description of the variables is presented in Table 3.

The economic environment of firms has been significantly affected by the various types of restrictions introduced during the pandemic. Accounting for this impact in our models is important as economic circumstances and shocks are correlated with firm performance. In this context, the average stringency index value is used as a proxy for the impact of the COVID-19 outbreak on firms' operations. It is calculated based on the Oxford COVID-19 Government Response Tracker (OxCGRT) scores from 1 January 2020 to the date of the follow-up survey.

**Table 3: Description of the Variables**

Variables	Source	Description
<i>Dependent Variables</i>		
Sales (1=decrease)	FU	1 – if the firm’s sales for the last completed month decreased from the same month in 2019
Demand (1=decrease)	FU	1 – if the demand for products and services of the firm for the last completed month decreased from the same month in 2019
Worked hours (1=decrease)	FU	1 – if the total number of hours worked by the firm per week for the last completed month reduced from the same month in 2019
Export share (1=decrease)	FU	1 – if the percentage of direct and indirect exports for the last completed month decreased from the same month in 2019
<i>Explanatory variables</i>		
Night-time light (1=increase)	NOAA/NCEI	1 – if the difference between monthly VIIRS stray light on the date of the baseline survey and the date of the follow-up survey is positive
Stringency index	OxCGRT	Stringency index (Hale et al. 2021) calculated for the period from 1 January 2020 to the interview date of the follow-up survey
Online business activity	FU	1 – if the firm has started or increased online business activity during the pandemic
Firm size	BS	1 – micro; 2 – small; 3 – medium; 4 – large
Industry	BS	1 – food; 2 – retail; 3 – manufacturing, garments; 4 – metal, machinery, and equip. mineral; 5 – services
Competition	BS	Number of competitors faced in the main market in which the firm sells its main product
KPI	BS	1 – if the firm has a formalized, written business strategy with clear key performance indicators
Gender of manager	BS	1 – if the manager is female; 0 – if the manager is male
Female ownership	BS	1 – if there are any women among the owners of the firm
Foreign ownership	BS	Percentage of the firm owned by private foreign individuals, companies, or organizations (in %)

Note: BS, FU, OxCGRT, NOAA/NCEI, and KPI indicate the baseline survey; the follow-up survey; the Oxford COVID-19 Government Response Tracker; the National Oceanic and Atmospheric Administration’s National Centers for Environmental Information; and Key Performance Indicators, respectively.

Source: The World Bank, Enterprise Surveys (<http://www.enterprisesurveys.org>; accessed 10 October 2021); Hale et al. (2021); and the National Oceanic and Atmospheric Administration’s National Centers for Environmental Information (<http://www.nsof.class.noaa.gov>).

The methodology for calculating the index indicating the severity of restrictions on the mobility and activity of people and firms was described by Hale et al. (2021). The calculation of the index is based on recommendations and requirements for the closure of public institutions and transport; bans on travel and leaving the house; meetings and mass events; and the availability of information (Hale et al. 2021). The index takes a value from 0 to 100. An index value close to 0 indicates the softness of the restrictions applied, while an index value equal to 100 means the maximum possible rigidity of the restrictions.

Our model specifications suggest that changes in night-time light intensity, i.e., economic activity, along with other explanatory variables can explain the likelihood of reduced performance due to the COVID-19 pandemic. In our models, night-time light intensity is used as a proxy for the economic activity of firms in some CAREC countries. This study applies one of the most commonly used sources of night-time light data, the Suomi National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer Suite (NPP-VIIRS). The data are also publicly available on the website of the National Oceanic and Atmospheric Administration’s National Centers for Environmental Information (NOAA/NCEI). Night-time light data are used at the regional level since this is the lowest geographic level for which business survey data are

available. VIIRS Stray Light Corrected Night-Time Day/Night Band Composites Version 1 is obtained through Google Earth Engine cloud computing technology to estimate the regional economic activity (development). The spatial granularity of night-time light data has been found to be very useful for regional studies.

In this regard, it is necessary to measure changes in the intensity of night-time light during the pandemic compared with the pre-pandemic period. To measure change in the night-time light intensity, we take the difference between the average night-time light on the date of the follow-up survey and that in the same month in 2019 for Georgia and Mongolia. For Azerbaijan and Kazakhstan, we take the difference between the dates of the follow-up survey and the baseline survey since the months of the previous period do not refer to the pre-pandemic period.

The difference values range from negative to positive. However, there are surprisingly few observations with a negative value. This study uses positive NTL changes instead of negative ones as this approach provides greater variability among observations in these circumstances. Thus, we use a dummy variable that takes the value 1 if the intensity of night-time light was stronger than in the pre-pandemic period.

Our empirical strategy follows the previous literature to explain economic performance with NTL data. However, one may argue about the potential reverse causality from economic performance to NTL. Thus, higher economic performance may lead to greater NTL intensity. The solution to this issue requires the use of exogenous variables, which is non-trivial issue given the limited scope of the data at the firm level (Freedman and Sekhon 2010; Baum et al. 2012). Though this causality is potential and our empirical model may result in biased estimation results, the empirical literature has concluded that NTL intensity successfully explains the level of economic activities both at the macroeconomic and at the firm level (Chen and Nordhaus 2011; Henderson, Storeygard, and Weil 2012; Tanaka and Keola 2017). In addition, as described above in our analysis, both firm performance and NTL take into account lagged values as they are measured in relative terms compared with the previous year or the pre-COVID-19 period. This may help to reduce the potential reverse causality.

## 5. RESULTS

Two waves of survey data are only available for Georgia and Mongolia, and basic firm characteristics are available in the baseline survey only. Therefore, assuming that firms do not show much variability in their characteristics over the 2-year period of the follow-up survey, a cross-sectional approach is used. The marginal effects are reported in Table 4, and the coefficient estimates are presented in Appendix Table A1. The estimation results are for the outcome variables: dummy variables indicating whether the sales, demand, share of exports, and hours worked per week have declined.

The estimated coefficients for night-time light show a positive impact on the likelihood that firms' performance in sales and demand will improve. These results indicate that, as the night-time light increases, the likelihood of deterioration in the performance of sales and demand is reduced. Thus, our results are consistent with the existing literature showing that night-time light can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander et al. 2015; Li et al. 2017; Kabanda 2022). However, the impact of NTL on the export share and working hours is not significant.

According to the results, the stringency index has a positive impact on the likelihood that firms' performance in sales, demand, and working hours will improve. This finding may suggest that firms gradually adapted to the new realities and reported less evidence of decreasing firm performance due to the strictness of lockdown-style policies (Aseinov et al. 2022) or due to the inappropriateness or effectiveness of a government response to the COVID-19 pandemic, i.e., of the strictness of "lockdown-style" policies.

**Table 4: Estimation Results (Marginal Effects)**

Variable	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
Night-time light (1=increase)	-0.0907*** (0.0314)	-0.0687** (0.0336)	-0.0437 (0.0966)	-0.0107 (0.0332)
Stringency index	-0.0298* (0.0173)	-0.108*** (0.0180)	-0.0158 (0.222)	-0.0762*** (0.0182)
Online business activity	0.0184 (0.0224)	0.0201 (0.0239)	-0.0634 (0.0712)	0.0145 (0.0243)
Gender of manager	0.0452 (0.0285)	0.0874*** (0.0301)	0.100 (0.0803)	-0.000995 (0.0302)
Female ownership	0.0508* (0.0262)	0.00901 (0.0280)	0.0930 (0.0747)	0.0654** (0.0281)
Foreign ownership	0.00066 (0.000474)	0.0012** (0.00052)	0.00149 (0.0012)	0.00046 (0.00051)
Competition	-2.12e-05 (1.72e-05)	4.18e-06 (1.95e-05)	-0.00018** (7.42e-05)	-2.74e-05 (1.95e-05)
KPI	-0.0191 (0.0209)	-0.0381* (0.0223)	0.0196 (0.0704)	-0.00490 (0.0229)
Firm size (reference category: Micro)				
<i>Small</i>	-0.0473 (0.0727)	-0.0383 (0.0807)		-0.195** (0.0783)
<i>Medium</i>	-0.0733 (0.0737)	-0.0611 (0.0818)		-0.195** (0.0793)
<i>Large</i>	-0.129* (0.0771)	-0.165* (0.0850)		-0.273*** (0.0823)
Industry (reference category: Food)				
<i>Retail</i>	0.0083 (0.0354)	-0.0443 (0.0376)	-0.327*** (0.109)	-0.0077 (0.0376)
<i>Manufacturing, Garments</i>	0.0639** (0.0326)	0.0367 (0.0351)	0.0695 (0.113)	0.0499 (0.0356)
<i>Metal, Machinery and Equipment, Mineral</i>	0.0408 (0.0430)	0.0212 (0.0476)		0.0528 (0.0487)
<i>Services</i>	0.0686** (0.0315)	0.0868** (0.0337)	0.0702 (0.102)	0.0829** (0.0343)
Country dummy	+	+	+	+
Observations	2,144	2,174	207	2,176

Notes: Standard errors are in parentheses. \*\*\*, \*\*, and \* represent statistical significance of 1%, 5%, and 10%, respectively. KPI stands for key performance indicators.

Most female-led and/or foreign-owned firms experienced a decline in the demand for their products and services compared with male-led and/or domestic-owned firms. In addition, firms with female owners are more likely to experience declines in sales, though this effect is valid at a lower level of statistical significance. This particular finding, that firms with female managers suffered most from a decrease in demand, might be related to the fact that the firms managed by women are in retail sales and services. These sectors suffered the most during the initial months of the COVID-19 pandemic with lockdown restrictions on mobility.

The presence of officially defined key performance indicators and more competitors is likely to have helped firms to maintain their performance, especially their demand and export share, during the pandemic. These results are consistent with the general expectation that effective coordination between the management and the production of a firm contributes to its performance.

As for the firm size covariates, they indicate that larger firms are more likely to maintain their performance than smaller firms. This result highlights that small and medium-sized firms are in a disadvantageous position when facing the challenges caused by COVID-19.

The marginal effects for industry dummies reveal interesting results. The sales volume of firms in the manufacturing, clothing, and service sectors are more likely to decline than that of firms in the food sector. Along with this, the results point to a significant decline in the performance of firms operating in the service sector compared with the food sector during the pandemic.

## 6. CONCLUSIONS AND POLICY IMPLICATIONS

This study examines economic activity measured with firm performance indicators using the changes in intensity of night-time light in four CAREC economies: Azerbaijan, Georgia, Kazakhstan, and Mongolia. The empirical analysis is based on the World Bank Enterprise Survey (WBES) data for 2019 and the follow-up survey during the COVID-19 pandemic. The Enterprise Survey dataset is enhanced with data on night-time light intensity from Google Earth and the strictness of “lockdown-style” policies, i.e., the stringency index from Hale et al. (2021). Using the probit regression model, this study investigates the impact of COVID-19 on firm performance and night-time light in CAREC countries. Firm performance is measured using four variables: decreases in sales, demand, export share, and working hours. The paper provides important results, which are summarized in Figure 14

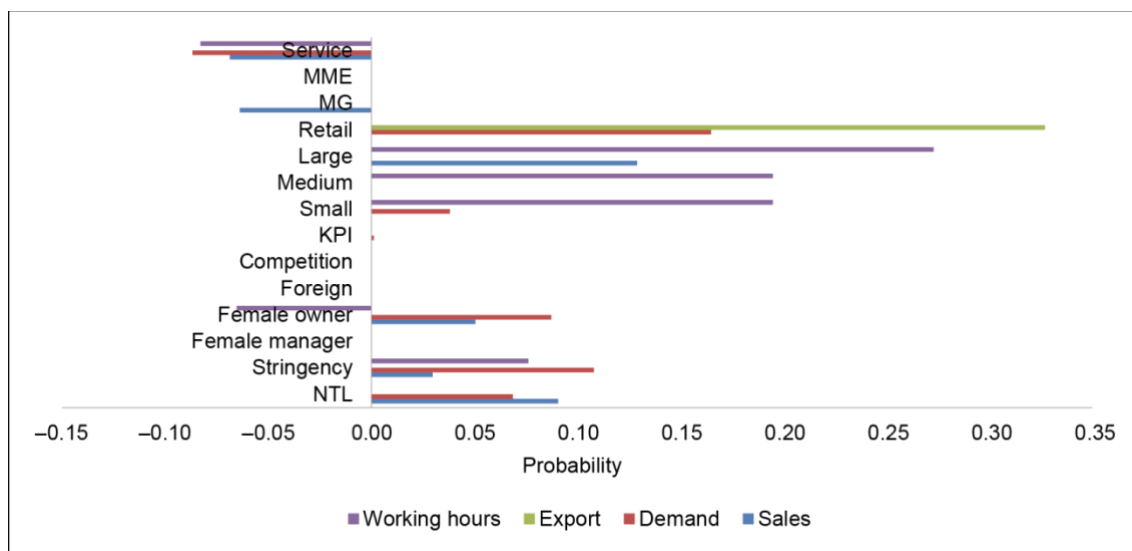
Firstly, our results show that, as night-time light increases, firms’ sales and demand are more likely to increase. Thus, night-time light can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander et al. 2015; Kabanda 2022). Secondly, the strictness of “lockdown-style” government policies, i.e., the stringency index, does not harm firm performance on average. Conversely, the stringency index even shows improvements to firm performance (sales, demand, and working hours). There could be several reasons for this result: firms were able to adjust to government measures to respond to COVID-19, less effective lockdown measures were imposed, or firms from areas with a higher stringency index received greater government support. Thirdly, the sales in the manufacturing, clothing, and service sectors are more likely to decline than those in the food sector. Along with this, the results point to a significant decline in the performance of firms operating in the service sector compared with the food sector during the

pandemic. Finally, large firms are more likely to have a better performance than micro, small, and medium-sized enterprises (MSMEs).

However, three main limitations of this study can be mentioned. First, though NTL data can provide detailed information on light intensity at higher frequency, the performance indicators from the business survey data used in the study refer to a comparison with the previous year. This limits the use of fine-grained data at a higher frequency resolution to track firm performance. Second, the main characteristics of firms in the business survey data are from the baseline survey carried out before the COVID-19 pandemic. Although the basic characteristics of firms do not change very frequently, it would be interesting to take into account potential changes in those characteristics during the COVID-19 pandemic too. Third, limited data on firms and their history restrict the identification of a valid exogenous variable that would be useful for providing robust estimation results due to the potential reverse causality issue.

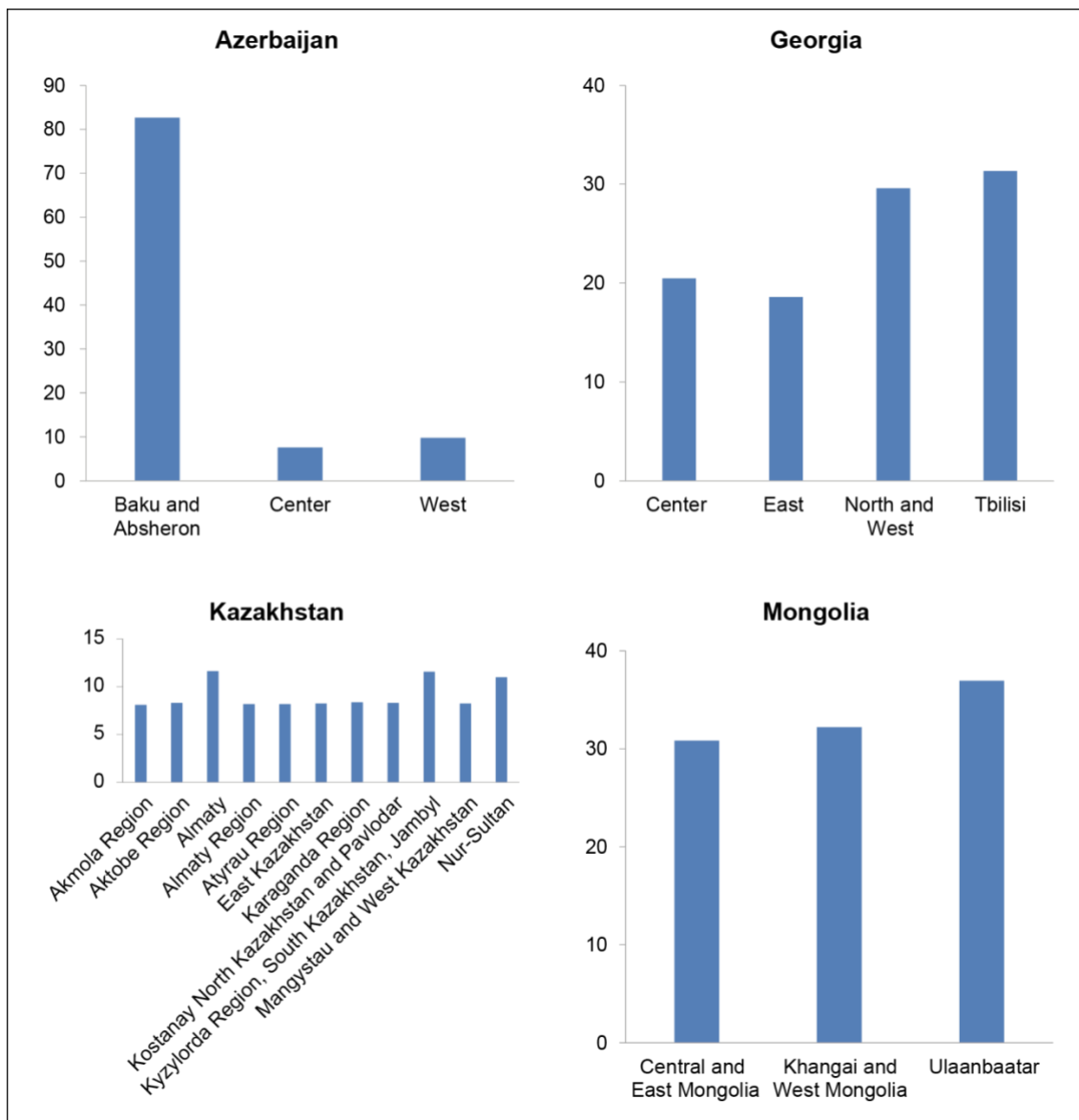
Despite its potential limitations, the findings of the study have several policy implications. First, the study highlights that NTL intensity data are useful for understanding economic dynamics not only at the country level but also by regions within a country. This is particularly important in developing countries with less reliable statistics on economic performance. Second, the findings indicate that the severity of the challenges faced by firms differs by sectors of the economy. Thus, the manufacturing, clothing, and service sectors are in greater need of support than other sectors. Third, the results point out potential unequal recovery among firms during the post-COVID-19 period. MSMEs are in greater need of support than large firms. Therefore, special focus on micro and small firms for loans and other types of government support mechanism would increase the social and economic effects of the post-COVID-19 recovery policy.

**Figure 14: Summary of the Results**



## APPENDIX

**Figure 1A: Distribution of the WB Full Sample across Sectors<sup>a</sup>**  
(%)

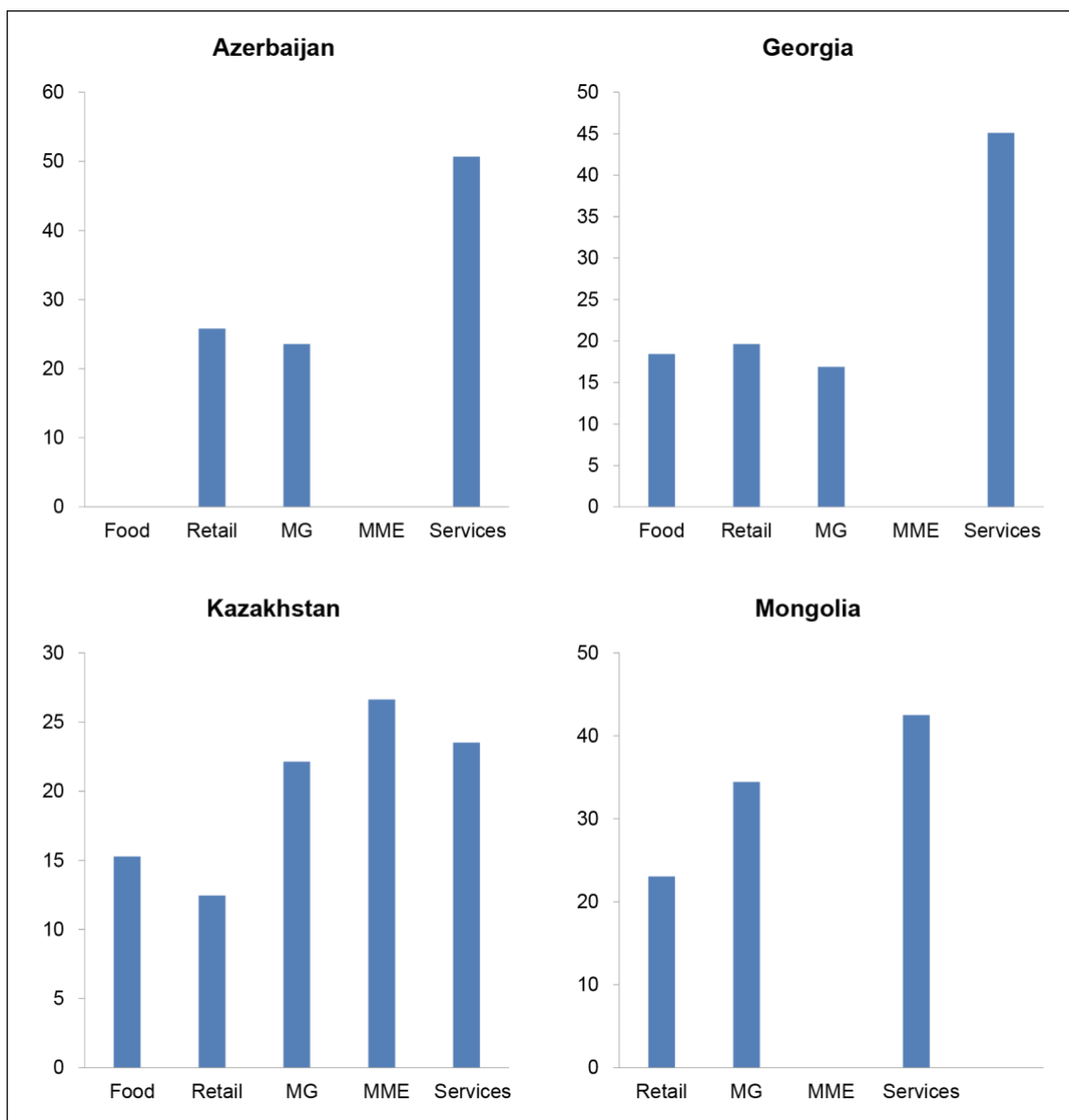


<sup>a</sup> Statistics on the number of firms surveyed by company size, ownership characteristic, and line of business are provided by the WB. Download file (Excel, 342KB) (<https://www.enterprisesurveys.org/en/survey-datasets>).

Source: Authors' own using data from the World Bank (2022) Business Enterprise Survey.

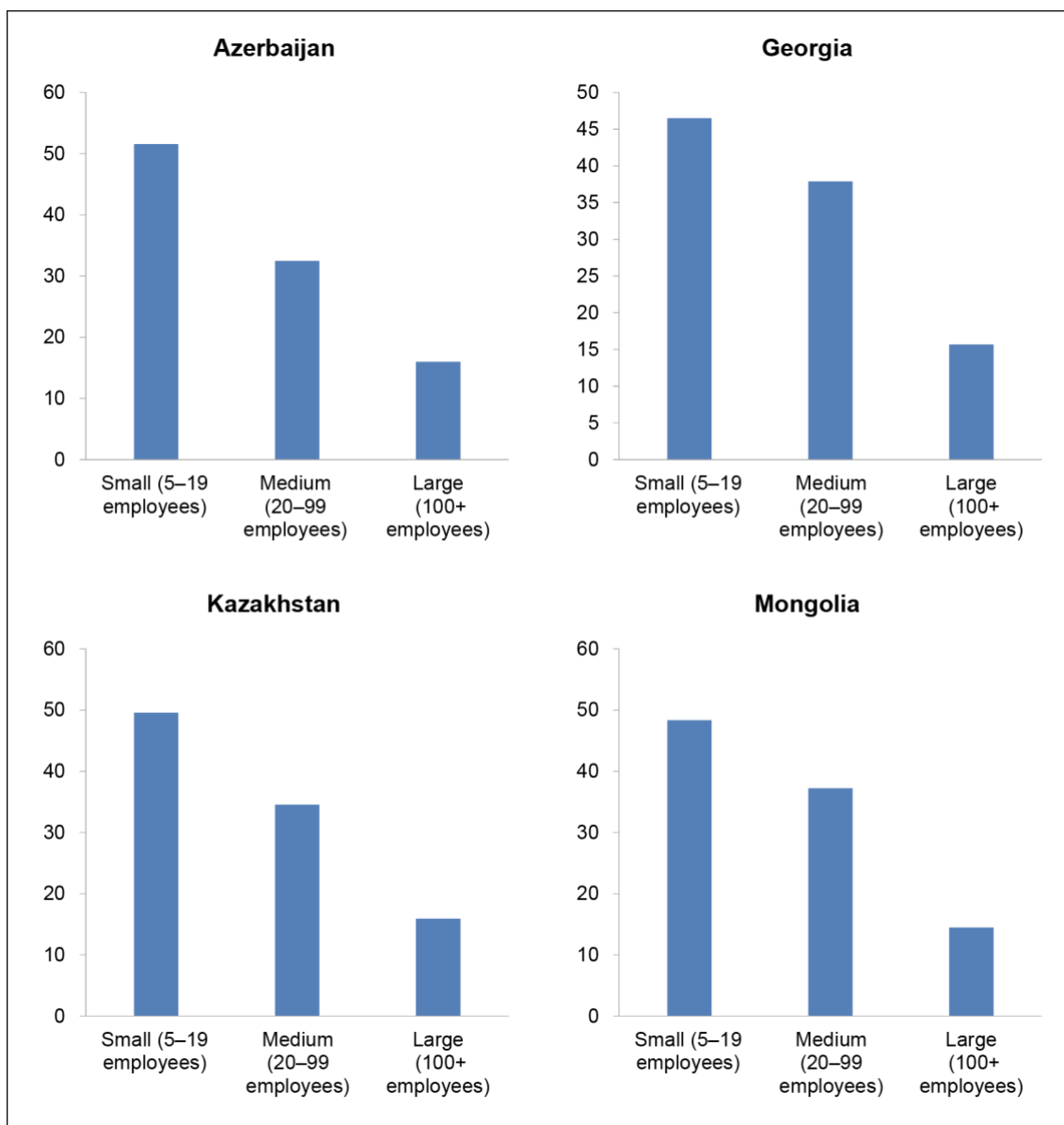


**Figure 2A: Distribution of the World Bank Enterprise Survey Sample across Sectors (%)**



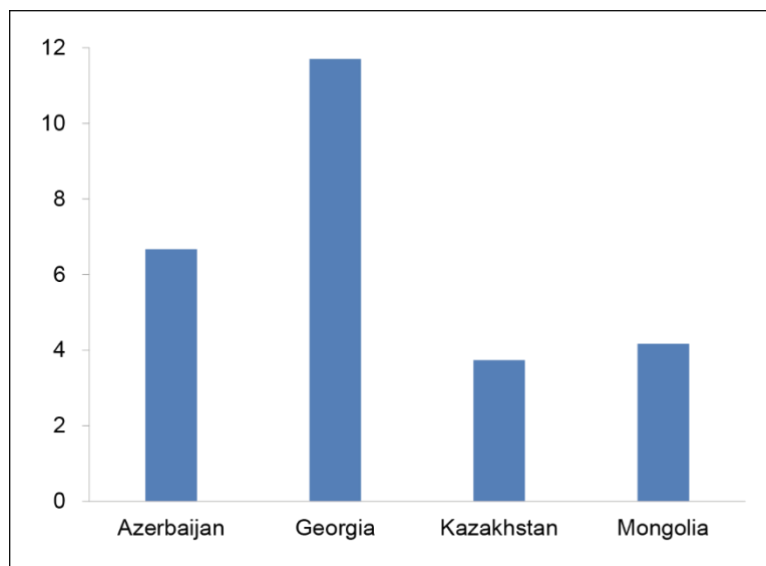
Source: Authors' own using data from the World Bank (2022) Business Enterprise Survey.

**Figure 3A: Distribution of the World Bank Enterprise Survey Sample across Firm Sizes (%)**



Source: Authors' own using data from the World Bank (2022) Business Enterprise Survey.

**Figure 4A: Share of Firms with Foreign Ownership (%)**



Note: Firms are considered as foreign owned when 10% or more of the firm is owned by foreign private individuals, companies, or organizations.

Source: Authors' own using data from the World Bank (2022) Business Enterprise Survey.

**Table 1A: Estimation Results of Probit Models on the Probability of a Decrease in Firms' Performance during the COVID-19 Pandemic (Coefficients)**

	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
Night-time light (1=increase)	-0.283*** (0.0984)	-0.189** (0.0928)	-0.147 (0.326)	-0.0287 (0.0888)
Stringency index	-0.0931* (0.0541)	-0.299*** (0.0506)	-0.0532 (0.748)	-0.204*** (0.0494)
Online business activity	0.0574 (0.0697)	0.0554 (0.0658)	-0.213 (0.241)	0.0389 (0.0650)
Gender of manager	0.141 (0.0890)	0.241*** (0.0834)	0.337 (0.273)	-0.00267 (0.0809)
Female ownership	0.158* (0.0820)	0.0248 (0.0771)	0.313 (0.255)	0.175** (0.0756)
Foreign ownership	0.00204 (0.00148)	0.00335** (0.00143)	0.00503 (0.00408)	0.00122 (0.00136)
Competition	-6.61e-05 (5.36e-05)	1.15e-05 (5.38e-05)	-0.000610** (0.000259)	-7.34e-05 (5.22e-05)
KPI	-0.0594 (0.0652)	-0.105* (0.0617)	0.0660 (0.237)	-0.0131 (0.0613)
Firm size (reference category: Micro)				
<i>Small</i>	-0.160 (0.258)	-0.109 (0.233)	-0.466 (0.336)	-0.551** (0.244)
<i>Medium</i>	-0.241 (0.260)	-0.172 (0.236)	-0.713** (0.334)	-0.550** (0.247)
<i>Large</i>	-0.406 (0.268)	-0.450* (0.244)		-0.758*** (0.254)
Industry (reference category: Food)				
<i>Retail</i>	0.0245 (0.104)	-0.118 (0.101)	-1.200*** (0.404)	-0.0206 (0.101)
<i>Manufacturing, Garments</i>	0.196** (0.0986)	0.0996 (0.0951)	0.212 (0.350)	0.133 (0.0950)
<i>Metal, Machinery, and Equipment, Mineral</i>	0.123 (0.131)	0.0575 (0.129)		0.141 (0.130)
<i>Services</i>	0.211** (0.0950)	0.240*** (0.0923)	0.214 (0.316)	0.222** (0.0916)
Country dummy	+	+	+	+
Constant	7.498** (3.653)	20.67*** (3.419)	4.069 (41.42)	14.18*** (3.336)
Observations	2,144	2,174	207	2,176
Pseudo R-squared	0.0649	0.0563	0.244	0.0594
LR	168.4	164.8	69.67	179.2
P-value	0	0	2.21e-09	0
LogLik	-1,213	-1,381	-107.8	-1,418

Notes: Standard errors are in parentheses. \*\*\*, \*\*, and \* represent statistical significance of 1%, 5%, and 10%, respectively.

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