The Impact of Lockdown Stringency on Employment : A Causal Analysis of the ICT and Contrasting Sectors

by

Jannatin Tajreen Raiyan
21205011

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Declaration

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3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.

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_____

Jannatin Tajreen Raiyan

21205011

Approval

The thesis titled “The Impact of Lockdown Stringency on Employment : A Causal Analysis of the ICT and Contrasting Sectors.” submitted by
1. Jannatin Tajreen Raiyan (21205011)
of Fall, 2021 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Social Science in Economics.

Examining Committee:

Supervisor:
(Member)

_____
ASM Shakil Haider, PhD
Assistant Professor, Department of Economics and Social Sciences
BRAC University

Program Coordinator:
(Member)

_____
Tanvir Sobhan
Senior Lecturer, Department of Economics and Social Sciences
BRAC University

Head of Department:
(Chair)

_____
Wasiqur Rahman Khan, PhD
Chairperson, Department of Economics and Social Sciences
BRAC University

Abstract

Inspired by the increasing interest in the policy and sectoral dynamics during the COVID-19 pandemic, this paper aims to study the causal effects of government mandated lockdown policy stringency on the Information and Communication (ICT) sector, including four contrasting sectors which are Arts, Entertainment & Recreation; Construction; Transport & Storage; Accommodation & Food. This paper employs the Generalized Synthetic Control (GSCM) method to study the effect across a panel of 22 countries from 2010-2023. The results found that lockdown policy measures had a strongly positive effect on employment in the Information and Communication sector with presence of heterogeneous effects in the contrasting sectors. The study finds the results in line with existing literature and the additional analysis of the contrasting sector add to the validity of the positive causal effects in the ICT sector. This thesis includes detailed evaluation of the causes and future policy implications of these effects.

Keywords: employment, policy stringency, COVID-19, lockdowns

Dedication

To my parents and my younger self, thank you for your patience.

Acknowledgement

Firstly, all praise to the Great Allah for whom this thesis has been completed without any major interruption.

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Nomenclature

ICT	Information and Communication sector
GSCM	Generalized Synthetic Control Method
ATT	Average Treatment Effect on Treated

Chapter 1

Introduction

COVID-19, the 21st century pandemic that shook the global economy and cast a long shadow of uncertainty over labor markets. What began as a complete halt to all traditional in-person trade due to government mandated lockdown measures, triggered a transition of all economic activities and daily tasks to digital platforms. The lockdown stringency demanded an urgent need for contactless labor, remote productivity and digital scalability that helped accelerate the adoption of technologies that now pose a strong threat to manual labor. These shifts not only redefined how work is perceived but have also reshaped the structure of labor markets worldwide, exposing the structural divides across industries, and nations as the pre-existing digital access disparities become the fault line for employment shocks during COVID (Jahan & Zhou, 2023), with some sectors adapting and some facing severe damage.

Covid-19 emphasized on differentiating sectors based on concepts such as ‘teleworkability’, it is the ability to work remotely, which became a crucial policy requirement on all levels such as health, business, economy and individual; the categorization was based on high and low teleworkability of jobs. Empirical studies underscore that teleworkability was a fairly new phenomenon during covid and played an important role in the shocks faced by the labor market, where non-teleworkable jobs faced sharp decline (Zhang et al., 2024; Kotyrlo, 2024). Essentially, high teleworkability of a job meant the tasks could be carried out remotely whereas a low teleworkability would mean the former scenario is not possible, and employment is likely to be hampered in the presence of strict lockdown measures. Thereby, most of the jobs that could shift to remote work did so as quickly as possible by rapidly adopting digitized mode of work (Bartik et al., 2023), while those that could not remained uncertain about their job status.

While the general patterns are well established, this paper focuses on providing a robust causal study to quantify the effects of lockdown stringency on a digitally fluent sector like Information and Communication. The study also strategically incorporates analysis of four contrasting sectors based on variation in their capacity for telework, and the sectors are: Arts, Entertainment & Recreation; Construction; Transport & Storage; Accommodation & Food. In accordance with existing literature, the expected heterogeneous results from these contrasting sectors will serve to validate the empirical model, thereby strengthening the causal interpretation of results in the ICT sector, such that lockdown policies systematically benefitted employment in the sector.

Chapter 2

Literature Review

The COVID-19 pandemic shock the labor market faced was historically distinct in its speed and sectoral magnitude. This literature review analyzes how the pandemic policy stringency interacted with the structural and sectoral differences in an economy, and resulting effects in the labor market. Bartik et al. (2020) documented a devastating collapse in labor market, with the majority of the job losses taking place in a matter of two weeks and mostly consisted of low-wage service sectors like leisure & hospitality, in contrast to the previous recessions, which mainly affected the higher-paid sectors like manufacturing and construction the hardest. As a form of protection measures taken by the government, lockdown mandates forced people to stay, and shift to ways of remotely carrying out their daily tasks, such as work, school and other daily tasks. The ease of such a shift was fundamentally defined by the concept of ‘teleworkability’. Mouratidis and Papagiannakis (2021) posit that the increased requirement for isolation resulted in significant rise in telework in terms of teleconference, e-learning, shopping and telehealth, ;

reporting an increase of 49% . The study also found a statistically significant rise in telecommunication of 55%. In addition, Gupta et al. (2022) referred to ICT services as ‘surviving tools’, in the face of self-isolation, the sector played a pivotal role in keeping operations and connectivity alive. Furthermore, Giordani & Rullani (2020) explain that lockdowns served as an effective coordination tool, generating a positive network of externalities that triggered a cycle of higher demands resulting in higher supply of digital goods and services, meaning an ineradicable shift towards remote jobs facilities, digital skill, and methods and devices for online collaboration, and hence an opportunity of higher derived demand in the ICT labor market. The study also makes distinction between high and low digital equilibrium, and its importance in shaping consumer’s preference for digitization of tasks given the market is well capable of offering high quality services, while in another study by the EIB Investment Survey (2021) highlighted a major digital divide between small and large firms especially in Europe, this suggests that the pandemic can potentially escalate pre-existing disparity. On the other hand, evidence suggests sectors such as transportation, arts, entertainment, recreation and accommodation and food services, also characterized as ‘high-contact’ or ‘low-teleworkability’, were the ones to experience the most catastrophic declines in turnover as well as the slowest recoveries, as social distancing measures directly targeted their core activities (Dey-Chowdhury et al., 2022); the study also quantifies the fall in employment as 7.6% compared to low-contact jobs experiencing 1.7%. Also supported by the work of Zhang et al. (2024), which reveals low-teleworkability is associated with lower job retention, higher income losses and increased economic vulnerability. While the pandemic realized the social and economic value of sectors like the arts and entertainment, that helped reestablished social connectivity even in strict lockdowns through social media and artist collaborations, it also put forth the sector’s

vulnerability, and raised concerns regarding issues of unfair payment and no proper recognition of artist value in digital platforms, making it imperative to reevaluate sectoral significance and thereby, the targeted support (Jeannotte, 2021).

In conclusion, the existing body of research frames a clear narrative, that is, the COVID-19 lockdown policy shock resulted in drastic economic changes, explained by concepts such as teleworkability and its capacity within sectors. Even though the broader economic trends are well established, a robust causal analysis of how government mandated policy stringency affected employment in the Information and Communication (ICT) sector is warranted. The study design incorporates four contrasting sectors, using the expected heterogeneous effects in the sectors, consistent with existing literature, to verify that the empirical model does not just capture general pandemic shock and thereby. This approach, thereby, further supports the causal effects on employment in the ICT sector.

Chapter 3

Methodology

3.1 Research Design

This study dives into a quasi-experimental research design to attempt to estimate the causal effect of COVID-19 lockdown policy on employment. The study focuses on the policy effects in the ICT sector while also incorporating four contrasting sectors, Arts, Entertainment & Recreation; Construction; Transport & Storage; Accommodation & Food, a theory based selection exhibiting varied capacity for digital work.

The treatment effect is defined as the intensity and duration of government-mandated lockdowns, applied by the Stringency Index, a project of the Oxford Coronavirus Government Response Tracker (OxCGRT). The countries that implemented the most stringent measures and prolonged lockdowns constitute the treatment unit, while countries with the least stringent and short lockdowns are part of the control unit. The study utilizes annual time-series panel data that extends from 2010 to 2023, with 2020-2023 being the treatment period. This framework enables the estimation of varied lockdown policies effects on the labor market. The core of the identification strategy is that, if the model is correctly specified, it should yield a heterogeneous effect across the sectors, specifically, a positive effect in the ICT sector, and a mix of negative and null in the four contrasting sectors. This confirms the empirical model does not capture the general pandemic but sector specific shocks, thus validating the causal analysis of employment effects in the ICT sector.

3.2 Data Sources and Variable Construction

All data employed in this study are from secondary, publicly available sources.

Firstly, the outcome variables consisting of the employment data of various sectors, are sourced from the ILOSTAT database of the International Labour Organization (ILO). Each sector is classified into different divisions by the International Standard Industrial Classification (ISIC Revision 4), and the sectors with their respective divisions are as follows : Information and Communication (ICT) (Division J), Transportation & Storage (Division H), Arts, Entertainment & Recreation (Division R), Accommodation & Food Services (Division I), Construction (F).

For the covariates in the model, several country-level macroeconomic and technological variables were used. Controls that were included to account for the overall standard macroeconomic and economic resilience are: Annual Gross Domestic Product Growth (%),

Unemployment Rate (% of Total Labor Force) Tertiary School Enrollment (% gross); all were sourced from the World Bank database. In addition, the state of each country's digital development prior to COVID-19 shocks were accounted for using the following variables: Fixed Broadband (per 100 people), Annual Telecommunication Investment, which were sourced from the World Bank and International Telecommunication Union (ITU) databases, respectively. These are standard metrics in the study of the digital economy (ITU, 2024). The table below presents the variables in detail.

Variable	Description	Source	Time Span	Type
Information and Communication	Total employment in the sector; includes broadcasting, telecom, IT services, publishing, and film	ILOSTAT, ISIC Rev. 4	2010-2023	Annual
Arts, Entertainment & Recreation	Total employment in the sector; includes creative, arts, sports and recreational activities	ILOSTAT, ISIC Rev. 4	2010-2023	Annual
Construction	Total employment in the sector; includes building construction and civil engineering including new work, repairs, additions, alterations.	ILOSTAT, ISIC Rev. 4	2010-2023	Annual
Transportation & Storage	Total employment in the sector; includes land, water, air transport, freight,	ILOSTAT, ISIC Rev. 4	2010-2023	Annual
Accommodation & Food Services	Total employment in the sector; includes hotels, restaurants and catering	ILOSTAT, ISIC Rev. 4	2010-2023	Annual
Annual Gross Domestic Product Growth (%)	It is referes to the total income earned through the production of goods and services in a country during an accounting period.	World Development Indicators database, World Bank	2010-2023	Annual
Unemployment Rate (% of Total Labor Force)	It is the share of the labor force that is without work but available for and seeking employment.	World Development Indicators database, World Bank	2010-2023	Annual
Tertiary School Enrollment (% gross)	Measures total enrolment in tertiary education, regardless of age, as a % of population that corresponds to the tertiary education age group. It reflects the capacity of the higher education system.	World Development Indicators database, World Bank	2010-2023	Annual

Fixed Broadband (per 100 people)	It refers to the fixed subscriptions to high-speed public Internet, both residential subscriptions and subscriptions for organizations.	World Development Indicators database, World Bank	2010-2023	Annual
Annual Telecommunication Investment	It refers to the investment during the financial year made by entities providing telecommunication networks and/or services	International Telecommunication Union (ITU)	2010-2023	Annual
Stringency Index	Composite measure of lockdown policy strictness (0-100), based on school/workplace closure, travel bans, public transport closure, etc.	OxCGRT	2020-2022	Continuous

Tables 1: Variables description

For the construction of the sample, which initially consisted of 52 countries with available employment data. With some countries missing the entirety of covariates, and others missing data for Stringency Index, only 42 countries remained. Even then, most countries lacked full data availability and were missing for a few variables and years. This problem was tackled using country-based Kalman Smoothing (A.1, Appendix). The cumulative exposure to COVID-19 lockdown policies were measured in order to capture the intensity and duration of policy impact. Using this treatment variable, the 42 countries were divided into three sections: **a)** countries in the top 25% quartile formed the Treatment unit (high exposure), **b)** countries in the bottom 25% quartile formed the Control unit (low exposure), **c)** countries in the middle were excluded to allow for a stark contrast between the most and least affected countries.

So, the treatment and control units are as follows:

a) Treatment Unit/Countries: Argentina, Australia, Austria, Azerbaijan, Brazil, Cyprus, Greece, Italy, Kyrgyzstan, Spain, United States

b) Control Unit/Countries: Bulgaria, Croatia, Denmark, Estonia, Finland, Hungary, Iceland, Latvia, Lithuania, Norway, Switzerland.

3.3 Method and Empirical Model

This study employs the Generalized Synthetic Control (GSCM) method (Xu, 2017) to investigate how stringency led digitalization boom affected sectoral employment. The model is specified below:

$$Y_{i,t} = \delta_{i,t} D_{i,t} + X'_{i,t} \beta + \lambda_i' f_t + \varepsilon_{i,t}$$

Here, the $Y_{i,t}$ represents the employment outcome for country 'i' in the year 't'; $D_{i,t}$ is the treatment variable, representing the effect of stringency policy, the term $\delta_{i,t}$ represent the causal effect of interest in this study $X'_{i,t}$ is a vector of observed time varying covariates, and the $\varepsilon_{i,t}$ is the idiosyncratic error term. The term λ_i, f_t represents GSCM's core innovation. It refers to the interactive fixed effects which model unobserved common shocks (f_t ,i.e. global pandemic waves) and the heterogeneous effect on each country (λ_i).

The study opted for GSCM over the traditional causal inference methods like Difference-in-Difference (DiD) due to many reasons relative to the scope of this study. First of all, the pandemic was a global phenomenon that had heterogeneous impacts on economies, and the shock consisted of time-varying elements such as virus waves, and fluctuating consumer outlook. The popular DiD method would struggle with parallel trends assumption's requirement in such volatile conditions. However, the GSCM relaxes this assumption by adding an interactive fixed effects term ($\lambda_i' f_t$), which effectively controls for the latent factors and their varying effects across countries, isolating the general pandemic effects from the marginal effect of lockdown policy (Xu, 2017).

Second, the GSCM helps construct a counterfactual taking into account each of the treatment countries by assigning a weight to a combination of countries from the donor pool. The GSCM is an optimal choice for studies with multiple treated units, as applied to assess impacts of extreme weather events on population health (Sheridan et al., 2022). Thus, this process does not demand one ideal comparator control country for every treated unit, instead it utilizes the characteristics of multiple countries to estimate the counterfactual trend.

Furthermore, the method incorporates an internal mechanism, namely Cross-Validation (CV) for model validation. It selects the optimal number of latent factors (r*) that best capture pre-treatment trends, this allows the synthetic control to be built on a reliable & predictive model. The goodness-of-fit is evaluated using the Mean Squared Prediction Error (MSPE), this checks for the pre-treatment fit, a lower MSPE suggests more reliable synthetic control, hence, strengthening the counterfactuals. All the sectors estimated were bootstrapped at 1000.

Lastly, the method allows for transparent, and intuitive outcomes, including creating visual counterfactual trajectories to aid for assessing pre-treatment fit and post-treatment divergences.

The main quantity of interest is the Average Treatment Effect on Treated (ATT), the average of $\delta_{i,t}$.

3.4 Hypothesis

- **Null hypothesis (H_0):** COVID-19 lockdown policies had no effect on employment in ICT sector
- **Alternative hypothesis (H_1):** COVID-19 lockdown policies had positive effect on employment in ICT sector

3.5 Limitations

The causal estimand of this study is the effect of lockdown stringency on employment across different sectors, where the treated units represent high stringency and control units represent low stringency. It is imperative to highlight that this is not a study of effects of lockdown compared to 'no pandemic'; rather, it isolated the marginal effects of policy intensity within the context of global pandemic. In addition, complete availability of cross-national panel data is scarce. Although imputations were employed using robust methods, use of imputed data inherently introduces a degree of uncertainty, and is likely to have some noise, mostly random, However, with all the precautions taken, it is highly unlikely the limitations render the findings spurious or statistically artifactual.

Chapter 4

Results

4.1 Descriptive statistics

Table 2 presents the descriptive statistics for all variables for the pre-COVID-19 period (2010-2019). It consists of 240 observations (nobs) for each variable in the sample. The employment variables exhibit a noticeable amount of variation across the countries, as projected by the large difference between the minimum and maximum values and standard deviations relatively large compared to the means.

Variable	nobs	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Stdev	Variance
Unemployment Rate	240	2.70400E+00	4.91600E+00	7.07200E+00	8.55758E+00	1.08853E+01	2.76860E+01	5.20999E+00	2.71440E+01
Annual GDP Growth	240	-9.87678E+00	7.35477E-01	2.10025E+00	1.88331E+00	3.28656E+00	1.09155E+01	2.81700E+00	7.93548E+00
Tertiary Enrollment	240	1.92600E+01	6.08670E+01	7.44416E+01	7.39040E+01	8.63734E+01	1.43963E+02	2.18639E+01	4.78031E+02
Fixed Broadband	240	4.19774E-01	2.30129E+01	2.82725E+01	2.76965E+01	3.42841E+01	4.69124E+01	9.88084E+00	9.76310E+01
Telecom Investment	240	2.04384E+06	1.24465E+08	7.06876E+08	5.34772E+09	2.66389E+09	9.79000E+10	1.70149E+10	2.89506E+20
Information and Communication	240	7.02000E+00	3.04870E+01	9.82000E+01	4.01280E+02	1.80312E+02	6.30564E+03	1.08245E+03	1.17170E+06
Arts, Entertainment & Recreation	240	4.77500E+00	2.37710E+01	6.09375E+01	2.40673E+02	1.10964E+02	3.16927E+03	6.09495E+02	3.71484E+05
Construction	240	9.25500E+00	1.03845E+02	2.32614E+02	1.08414E+03	5.36251E+02	1.91078E+04	2.47828E+03	6.14185E+06
Transport & Storage	240	8.73800E+00	1.00764E+02	1.76415E+02	7.73059E+02	3.66544E+02	9.66313E+03	1.84514E+03	3.40453E+06
Accommodation & Food	240	7.89700E+00	3.83540E+01	1.11233E+02	8.42696E+02	3.53492E+02	1.05403E+04	2.09920E+03	4.40662E+06

Table 2: Pre-COVID-19 Descriptive Statistics

For instance, employment in the Information and Communication sector ranges from 7000 to 6.3 million, approximately, with a mean of around 401,000. The macroeconomic and technological control variables also illustrate considerable variation, revealing the heterogeneous nature of each economy, and levels of development within the sample. The ‘treat’ variable shows zeros for all observations, as it was used to assign treatment based on future (2020-2023) lockdown stringency which had not yet occurred.

Table 3 presents the post-COVID-19 descriptive statistics (2020-2023), consisting of 88 observations. The ‘treat’ variable now shows a mean of 0.5, confirming the sample is evenly split between treatment (high stringency) and control (low stringency) for the analysis. This post pandemic is characterised by significant economic volatility, as portrayed by the wide range and standard deviation of ‘Annual GDP Growth’ which includes large contractions of as low as -10.94% as well as strong recoveries of almost 12.63%.

Variable	nobs	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Stdev	Variance
Unemployment Rate	88	3.23E+00	4.58E+00	6.12E+00	6.81E+00	7.66E+00	1.59E+01	2.99E+00	8.92E+00
Annual GDP Growth	88	-1.09E+01	-1.04E+00	2.72E+00	2.04E+00	5.57E+00	1.26E+01	5.04E+00	2.54E+01
Tertiary Enrollment	88	3.64E+01	7.14E+01	8.47E+01	8.47E+01	9.58E+00	1.83E+02	2.47E+01	6.09E+02
Fixed Broadband	88	4.34E+00	2.74E+01	3.46E+01	3.25E+01	9.58E+01	4.79E+01	9.59E+00	9.19E+01
Telecom Investment	88	5.96E+12	1.74E+08	8.12E+08	6.19E+09	2.96E+09	1.10E+11	2.02E+10	4.08E+20
Information and Communication	88	9.13E+00	4.92E+01	1.24E+02	5.36E+02	2.75E+02	6.89E+03	1.39E+03	1.93E+06
Arts, Entertainment & Recreation	88	6.48E+00	2.76E+01	6.59E+01	2.56E+02	1.89E+02	3.14E+03	6.00E+02	3.60E+05
Construction	88	1.31E+01	1.18E+02	2.67E+02	1.23E+03	1.06E+03	1.24E+04	2.75E+03	7.56E+06
Transport & Storage	88	9.59E+00	1.04E+02	2.00E+02	9.47E+02	6.30E+02	1.08E+04	2.26E+03	5.12E+06
Accommodation & Food	88	9.65E+00	7.76E+01	1.52E+02	9.30E+02	4.14E+02	1.02E+04	2.15E+03	4.64E+06

Table 3: Post-COVID-19 Descriptive Statistics

Notably, the mean employment levels in sectors such as Information and Communication, Construction, and Transport & Storage are higher in the post- COVID period relative to the pre-COVID baseline, indicating an overall trajectory of growth or recovery. However, the continued high standard deviations indicates that post-COVID likely maintains the cross-country disparity. For instance, in the Accommodation & Food sector, one of the largest standard deviations (2,153,292), illustrates a devastating loss, with some being more resilient than others. The heterogeneity is well displayed by statistics, making it a case for methods like Generalized Synthetic Control designed to estimate causal effects even within such heterogeneous and volatile environments.

The following subsections (4.2 Main findings & 4.3 Contrasting sector findings) put forth the results derived from the Generalized Synthetic Control method. The findings demonstrate a highly heterogeneous impact, varying from precise null to large and statistically significant effects.The results are interpreted based on the confidence intervals, in accordance with standard statistical interpretation guidance against p-value for it is unreliable for inference for models like

Generalized Synthetic Control Method (Xu, 2017) and the preference is given to greater informational value of confidence interval (Wasserstein & Lazar, 2016).

Sector	Optimal r*	Average ATT	Confidence Interval	MSPE ratio
Infomation and Communication (ICT)	3	107.17	[14.98, 181.80]	80.24
Arts, Entertainment & Recreation	1	-46.2	[-67.70, -19.32]	31.6
Construction	4	1.61	[-22.74, 74.83]	23.74
Transport & Storage	5	106.31	[-30.23, 236.85]	77.04
Accommodation & Food services	4	-112.12	[-331.79, 86.29]	29.81

Table 4: Result Summary

Sector	Year	Post-treatment Year-by-year ATT	SE	Lower CI	Upper CI	p-value
Information and Communication (ICT)	2020	27.47	30.80	-22.78	105.06	0.3725
	2021	86.79	52.68	-21.82	179.43	0.0994
	2022	153.30***	45.22	57.12	242.46	0.0007
	2023	161.14***	58.42	32.12	268.31	0.0058
Arts, Entertainment & Recreation	2020	-96.86***	10.93	-118.56	-69.27	0.0000
	2021	-79.20***	10.57	-98.36	-55.39	0.0000
	2022	-18.83	20.86	-51.46	29.78	0.3666
	2023	10.10	19.47	-21.24	53.60	0.6041
Transport & Storage	2020	-10.85	80.58	-176.03	137.39	0.8928
	2021	79.04	88.22	-108.31	203.79	0.3703
	2022	180.43***	68.05	45.09	285.79	0.0080
	2023	176.61***	67.48	45.55	289.38	0.0089
Accommodation & Food	2020	-203.43**	80.23	-397.92	-51.68	0.0112
	2021	-89.09	120.34	-388.50	97.18	0.4591
	2022	-96.41	127.25	-336.90	166.21	0.4486
	2023	-59.55	93.19	-198.69	168.89	0.5228
Construction	2020	-151.64***	24.68	-185.40	-83.19	0.0000
	2021	-22.13	29.79	-60.00	54.11	0.4570
	2022	92.57***	24.76	71.15	162.16	0.0002
	2023	87.639126***	26.45	63.45	162.78	0.0009

Note: significance is given as *** 1%, ** 5%, and * 10%.

Table 5: Post-treatment year-by-year results

4.2 Main Findings

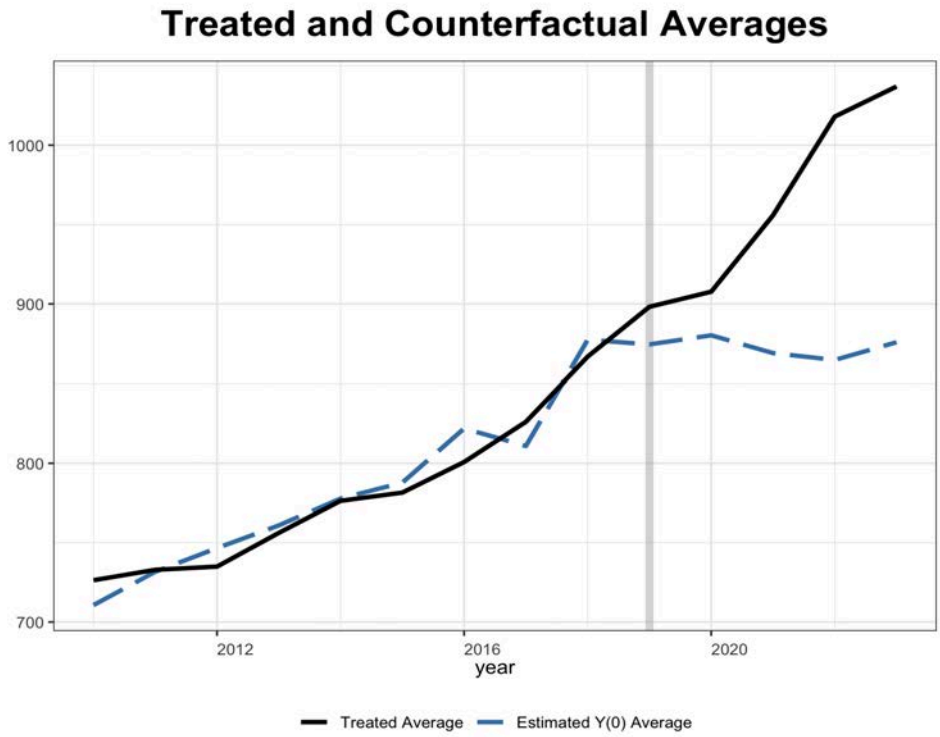

Figure 1: Information and Communication Sector Counterfactual

The results find a positive effect of stricter lockdown policies on the 'Information and communication (ICT)' sector employment. The average ATT is 107.17, at 95% confidence interval with the bootstrapped interval being [14.98, 181.80], as the interval does not include , the study can confirm the results are statistically significant. Thus the study rejects the null hypothesis.

The treatment effects portray a clear pattern of growth, with a substantial increase in the magnitude and solidifying effects over the latter years of the sample. In addition, the model achieved strong pre-treatment fit, optimizing the predictive accuracy. The intensity of the

post-treatment divergence is backed by a high pre/post MSPE ratio of 80.24, indicating a definitive break from the pre-treatment trend.

A low pre-treatment MSPE, as supported by the high pre/post MSPE ratio (i.e. 80.24), the synthetic control closely mirrors the actual employment trends before 2020. Therefore, the demonstrated significant divergence of the treated and the counterfactuals, provides credible evidence of a causal treatment effect as a result of lockdown policies.

In Figure 1, the blue dashed line is the synthetic control which is seen to be closely replicating the observed path of the sector which is indicated by the bold black line in the pre-treatment period from 2010 till 2019; with any gaps appearing to be random and unsystematic. However, immediately after the 2020 lockdown implementation, the two paths diverge significantly. The actual employment level in treated countries surges upwards, while the donor pool's counterfactual, with less stricter lockdowns, experience a relatively stable trajectory. The visual divergence signals the positive ATT estimates, growing significantly in size across the treatment period.

4.3 Contrasting Sectors Findings

4.3a Arts, Entertainment & Recreation

The analysis for the 'Arts, Entertainment and Recreation' sector produces a negative effect. The average ATT is -46.20 with the 95% confidence interval [-67.70, -19.32], as the interval does not include zero, the negative effect is confirmed to be significant. The impact was the largest in the immediate aftermath of the lockdown policy in 2020 before slowly recovering in the subsequent years. A pre/post MSPE ratio of 31.60 suggests a strong statistical evidence that signals the negative impact was a real departure from the counterfactual trends.

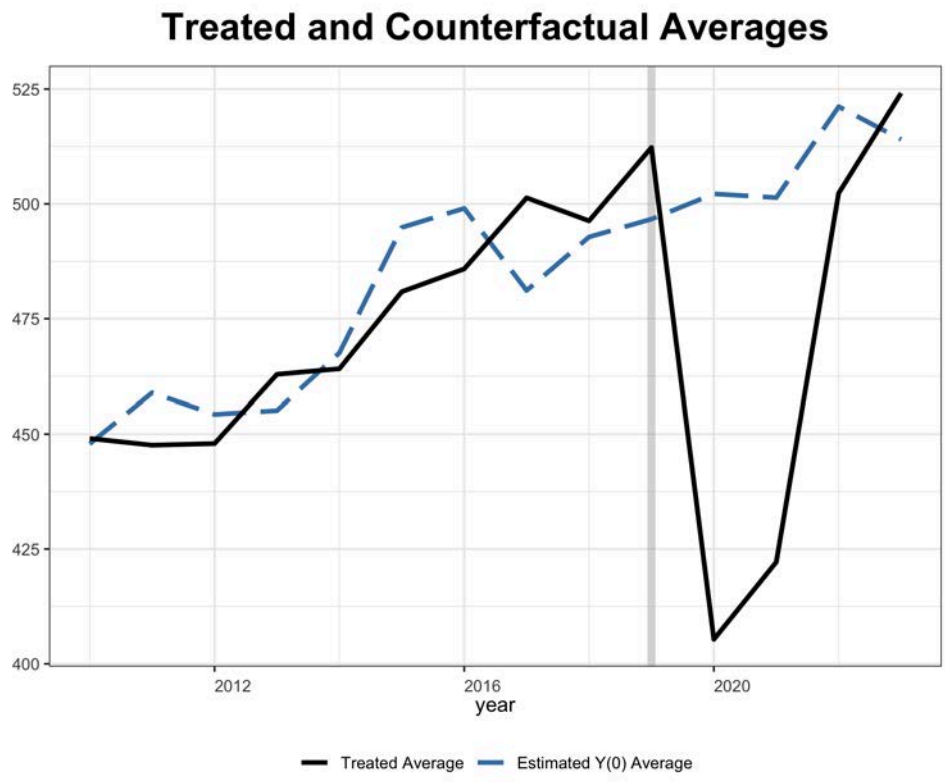

Figure 2: Arts, Entertainment & Recreation Sector Counterfactual

Figure 2 visualizes the estimated negative effect between the actual employment trajectory (the treated average) and the synthetic control counterfactual (the estimated Y(0) average). The drastic gap precisely after the strict lockdown policies were implemented, confirming the model's causal estimate. The sharp downturn of the treated countries relative to the stable path of its counterfactual portrays the severe employment shock experienced by the sector, consistent with its contact-intensive, crowd-based activities which were first to be eliminated by the lockdown measures.

4.3b Construction

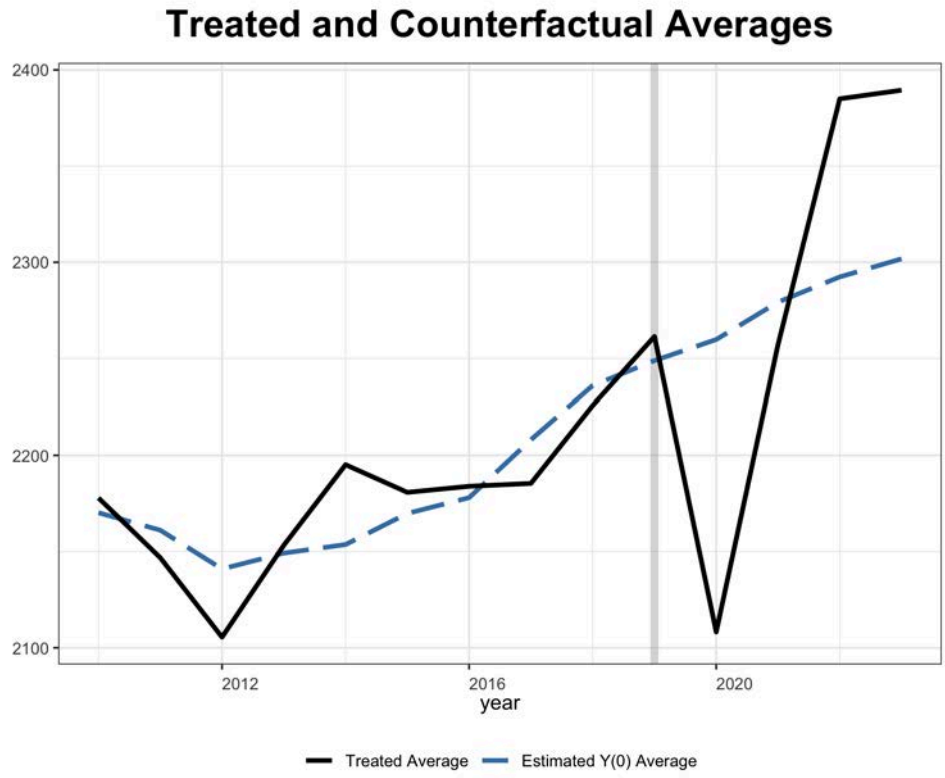

Figure 3: Construction Sector Counterfactual

The point estimate for the 'Construction' sector is a precise null effect. With 95% confidence interval confined around zero [-22.74, 74.83]. The effects of the policy reveal a sharp negative shock in early treatment period, 2020, followed by a solid recovery, resulting in a no net effect over the entire period. Here, a pre/post MSPE ratio of 23.73 suggests conditions worsened post-treatment and a higher divergence than compared to pre-treatment.

As illustrated in Figure 3, the null effect stems from the sharp initial shock followed by quick recovery. The synthetic control tracks the treated unit moderately in the pre-treatment segment, however, immediately after the lockdown, the sector witnesses a severe negative divergence, in accordance with the estimated negative ATT. But, this sharp fall was entirely compensated by a strong V-shape rebound by the sector resulting in the overall null effect. According to Table 5,

the sector experienced a more than double compensation going from -151.63 to -22.13 in a span of a year, and onto positive effect the following years.

4.3c Transport & Storage

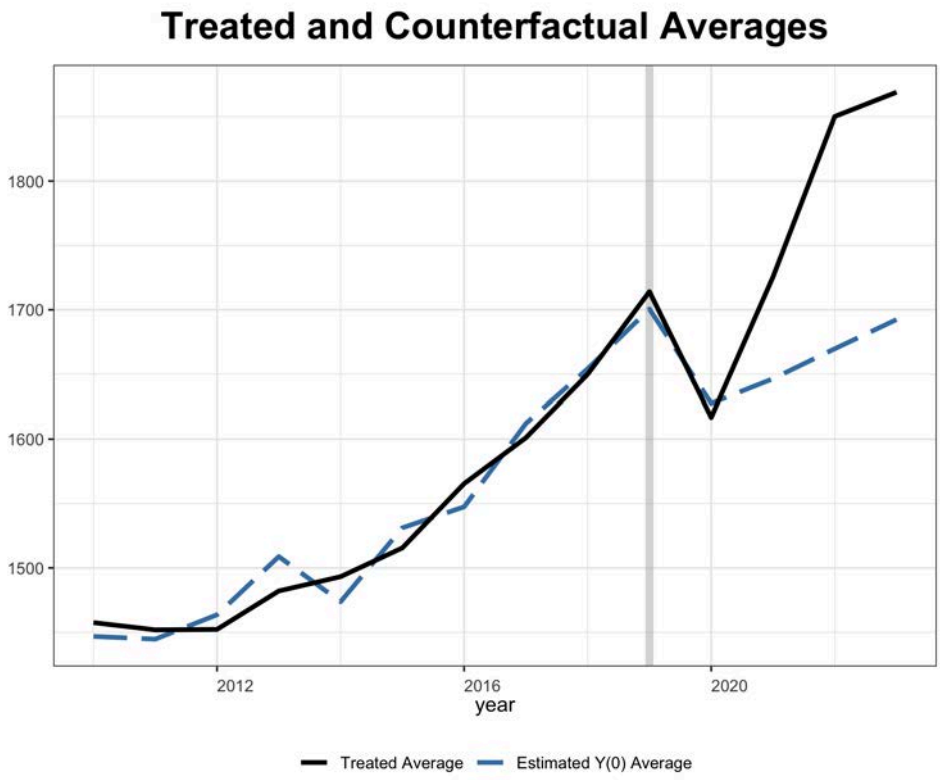

Figure 4: Transport & Storage Sector Counterfactual

For the ‘ Transportation and storage’ sector, the point estimate is positive but imprecise. The average ATT is 106.31, however, the 95% confidence interval is wide and includes zero [-30.23, 236.85]. The period specific effects present a modest negative impact in 2020 followed by large positive estimates over the years, as supported by Table 5.

The Figure 4 above displays the nuanced result of the sector. The paths of the treated units (Treated Average) and the counterfactual (Estimated Y(0) Average) show no immediate

sustained shock or divergence following the treatment but soon after the policy measures settled in there is notice be significant divergence between the treated and counterfactual with a pre/post MSPE ratio of 77.04; a significant positive effect also supported by Table 5 data.

4.3d Accommodation & Food

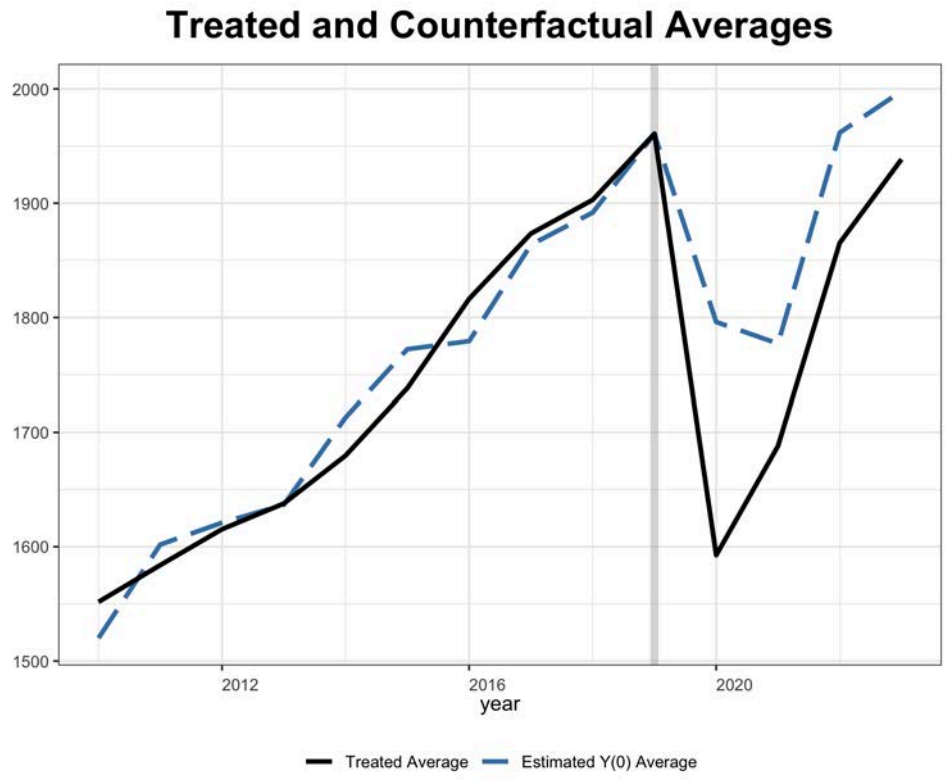

Figure 5: Accommodation & Food Sector Counterfactual

The point estimate for the 'Accommodation and Food services' sector is large and negative at -112.12 but the estimate is not precise, as the 95% confidence interval widely includes zero [-331.79, 86.29]. is in line with the industry's vulnerability to mobility restrictions, hence the findings suggest a reception of high volatility negative effects rather than a simple null effect.

Figure 5 shows divergence in the impact on employment with the treated units have a more sharp and drastic fall compared to the donor pool. Both the bold black line of the Treated Average and

blue dashed line of the Estimated Average move in parallel with the black line moving below the estimated average line, until the initial treatment period, 2020; the separation is quantified by the pre/post MSPE ratio of 29.81, which captures the high volatility of the sector.

4.4 Robustness Check

The reliability of the main findings, effects on ICT employment, were evaluated using a number of robustness checks, and they are as follows:

a) Cross-Validation and Model Fit (MSPE, RMSPE): GSCM incorporates interactive fixed effects that takes into account latent factors (r* =3). The optimal number of such factors (r) is selected by the process of cross-validation (CV), allowing better model specification with the highest predictive ability from the sample, ensuring a valid counterfactual. In addition, the goodness of fit is measured by the Mean Squared Prediction Error (MSPE) and the Root Mean Squared Prediction Error (RMSPE), approximately 77.16, which is quite small and indicates an excellent pre-treatment fit for the model with the synthetic counterfactual closely following the actual ICT employment trajectory up until policy shocks are observed from 2020 onwards.

b) Alternative Standard Errors: The model was assessed under three different SE methods using parametric, non-parametric (bootstrap), and jackknife.

   While all three methods produced solid results for the point estimate, the standard error reported by ‘Parametric’ is (48.50) whereas the two resampling methods bootstrap and jackknife produced closely similar standard errors, (75.58) and (78.66), respectively. This discrepancy is likely due to assumptions made by the parametric method, (i.e. i.i.d assumptions). The bootstrap and jackknife which make lesser distribution assumptions

are more robust and reliable when compared to parametric which may lead to idealized results and underestimate the true uncertainty. Thus, in this study the non-parametric (bootstrap) method is prioritized.

c) Placebo test: A series of 'Unit-Placebo' tests were conducted to assess the robustness of the findings. This test helps to conclusively rule out the possibility of spurious results. The procedure constitutes iteratively re-estimating the model using control countries and artificially assigning them 'treatment' status. The results are visualized in the plot below and in Appendix Table A.2.

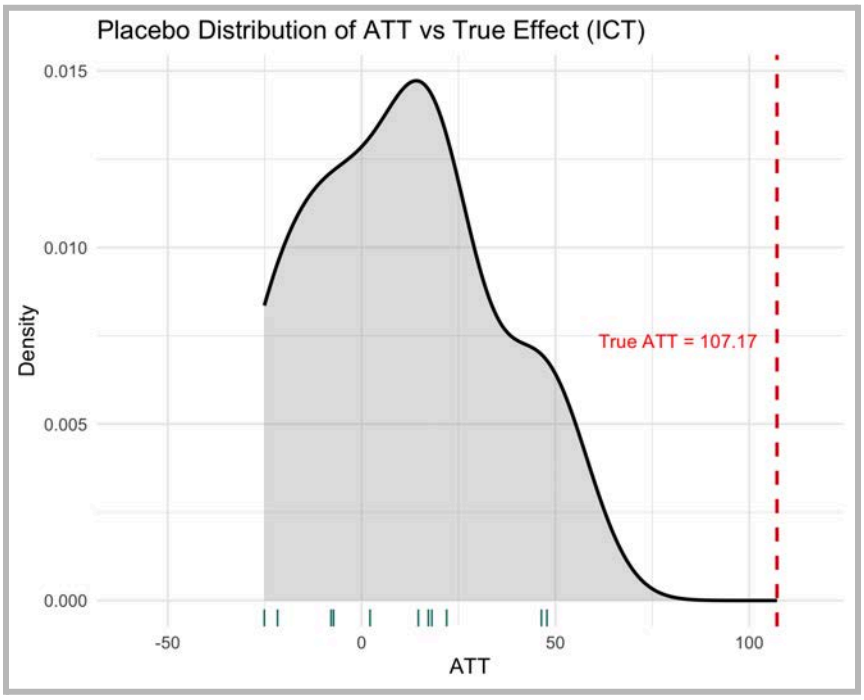

Figure 6: Placebo Test

The distribution of the placebo estimates are closely centered around zero, with the average ATT of 9.68, approximately. The confidence intervals for these placebo estimates are extremely wide, suggesting that the model finds no precise or significant effect for these artificially assigned untreated units. In contrast, the estimated ATT for the true treatment group (107.17) is a major positive outlier in terms of both the point estimate

and its confidence interval. This sharp disparity strongly suggests that the significant positive effect is uniquely linked to countries with highly stringent lockdowns and is unlikely to be a statistical artifact.

Chapter 5

Discussion

The findings of this study provide strong, quasi-experimental evidence by measuring the marginal effects of high stringency on the employment relative to a more lenient lockdown policy. This section delves into the theoretical and practical interpretation of the effects in firstly the ICT sector and then into the contrasting sectors, established within the context of existing literature on pandemic induced structural change that caused the significant reallocation of labor.

5.1 Information and Communication Sector

The findings show that Information and Communication sector employment sustained a positive effect due to policy stringency, with counterfactuals building evidence showing stricter policy led to higher positive effects. As per the lockdown stringency, governments restricted public gatherings, and consequently, closure of schools, workplaces and public venues, compelling people to shift to remote work, e-learning and other daily tasks (Mouratidis & Papagiannakis, 2021). These shifts massively increased demand for ICT services and consequently led to a digital surge with most traditional in-person working being carried out online as reasoned by De et al., (2020); also claimed by Barrero et al. (2021) the shift to remote work is highly likely a long term change that compels firms to intentionally invest in digital capital and infrastructure

and thus, increasing long-term demand for ICT labor. As seen in Table 5 the first treatment year, unlike the other sectors, the Information and Communication sector started with a positive employment effect, substantially growing in magnitude the following years.

In addition, increased adoption and investment of in these ICT services and digital technology by companies to improve customer experience and thereby, retain customers; as noted by Avalos et al. (2023) that the mechanism that drove the sector onto a higher trajectory was the fact that firms invested heavily in digital technologies in face of strict lockdowns and stay-at-home requirements, in order to aid online work operations and maintain productivity. According to a survey by the International Finance Corporation, around 45% businesses increased the use of and almost 28% invested in digital technologies (Avalos et al., 2023). Hence, the sector experienced a massive derived demand requiring more employment to keep up with the increasing demand.

5.2 Discussion of Contrasting Sectors

On the other end of the spectrum, the Arts, Entertainment and Recreation sector experienced a negative impact due to the mass closure of sites by the government-mandated lockdown measures. The entertainment and recreation sector thrives with its core activities being operating cinemas, theatres, concert venues and sports events, which were among some of the first public gathering scenarios to be explicitly and directly addressed by lockdown orders (i.e. capacity limitations, mandatory closures). These institutes used a combination of government aid and cost reduction methods to remain resilient during the crisis (Khlystova et al., 2022), which likely meant laying off workers and as cited previously, the job in the sector is characterised by low-teleworkability which means in a time of crisis like the COVID-19 pandemic, job retentions are likely to be very low. The counterfactual already accounts for the general pandemic shocks

(i.e. general fear, case rates) which are common across the similar countries. Therefore, the model was able to isolate the policy effect, suggesting the significant gap identified was captured due to the additional impact of differential stringency policy; this interpretation is reinforced by the factor loading analysis in Appendix A.4b, which shows a clear separation between high and low stringency countries.

Furthermore, the findings in the Construction sector suggest a null effect of the stringent lockdown policies on employment. With the confidence intervals being closely bounded around zero, adds assurance that, on average, this sector demonstrated exceptional resilience to the policies. Additionally, the findings align with the global narrative of transient shock accompanied by robust V-shape recovery, as Petojević et al., (2022) explained, despite the initial site closures & construction project disruptions, it was not found to have any significant damage due to the effective implementation of of modern management techniques; although, the crisis did not profoundly modernize the sector, it did, however, encourage project managers to consider new and more digitized approaches. As mentioned previously, compared to previous recessions which impacted higher paid sectors like construction, COVID-19 policies did not largely affect this sector. In addition, the government targeted infrastructure investments that played a major role in reviving economic growth in general, this also benefitted the construction sector with increased project demands (Ruddock & Ruddock, 2022). Therefore, the initial losses were quickly compensated and employment was maintained in this sector.

For the 'Transport & Storage' sector where the findings revealed an estimated positive yet statistically insignificant average effect mirrors the highly polarized pandemic experience of the sector due to policy stringency. The result is not an indication of 'no net effect' but rather of offsetting consequences within the sector's subdivisions, which the aggregate data was unable to

accurately identify. The factor loading (Appendix A.4c) also indicates opposing factors within the sector. Literature such as (Mack et al., 2021) claim that due to pandemic regulations, the workers in transportation industries were 20.6% more likely to lose jobs than workers in non-transport industries. The widespread lockdowns resulted in unprecedented declines in use of public transport, air travel and ride-sharing services. Additionally, Hovi and Pinchasik (2024) posit that despite the initial disruption in freight transport sustained increase in B2C deliveries, although there was a temporary decline in B2B deliveries; the study was done on a less stringent economy (i.e. Norway). The trajectory in Figure 4, indicates that without stringent lockdowns the sector would have experienced a modest upward trend. But, the treated units demonstrate a sharp fall in 2020, followed by a solid recovery, surpassing its synthetic counterfactuals from 2021 onwards. With higher stringency resulting in sharp pivot to e-commerce and the crucial need to keep up the supply chain for essential goods and services led to a substantial increase in demand for logistics, courier and storage services (Zenezini et al., 2023). The wide confidence interval is a statistical manifestation of this internal mismatch. The net effect, whether marginally negative or strongly positive, is heavily dependent on the composition of the sector in each country in the sample. Thus, what the result captured was essentially, two big economic forces of the sectors pulling in opposite directions during the pandemic.

The Accommodation & Food services sector indicates a large negative effect is unlikely to be a ‘no effect’, despite being statistical insignificance, as it is undoubtedly directionally correct and conforms to a strong body of evidence. Studies have consistently identified the Accommodation & Food sector, also known as the hospitality sector, as the epicenter of COVID-19’s brutal economic damage mainly because of the sector’s reliance on in-person operations, far exceeding

unemployment witnessed during 2008-2009 recession, and other industries (Aigbedo, 2021). The size of the estimate reflects the massive demand shock the sector faced due to lockdowns and mobility restrictions. The notable level of uncertainty around the negative estimate, the wide confidence interval, likely captures the nuances of real world complexity, thereby, interpretations should be contextualized within the structure of the treated and control units of this study. The treated units consist of countries with large, tourism-based economies within the European sphere (i.e. Italy, Spain, Greece) which were listed as some of the worst hit economies by the pandemic due to their inherent economic structure, according to the United Nation World Tourism Organization, the industry witnessed a staggering 80% decline in tourism (UNWTO, 2020b). The donor pool, on the other hand, consists of a mix of Eastern European and Baltic economies (i.e. Estonia, Latvia, Lithuania, Bulgaria, Croatia), typically less reliant on international tourism as a component of their GDP (Tuszyńska & Tynan, 2017). Hence, the effects of a lockdown, with variations in strictness, exposed the vulnerability of this high-contact industry. Consequently, the wide confidence interval likely reflects the underlying heterogeneous effects, thus, it does not invalid the result, instead it can be interpreted as amongst the stringent countries, the most affected were those where tourism was constituted as an economic pillar.

Chapter 6

Conclusion

This study aimed to estimate the causal impacts of COVID-19 lockdown policies on ICT sector employment to test the direct relationship between policy intensity and labor market outcomes, including a complementary study of the effect on contrasting sectors. The results convey clear, quasi-experimental evidence that the effects of the stringency of government mandated lockdown

had largely been heterogeneous across all sectors with an expected positive effect in the ICT sector, and a mix of null and negative impacts among the contrasting sectors. The findings of the study underscore that lockdown stringency was demanding of quick shifts to remote work and supported industries with inherent capacity for telework, creating an economic divide between winners and losers of the policy stringency. While the majority of the sectors, in line with existing literature, experienced an initial loss, the ICT sector was distinct in experiencing a positive effect from the beginning of the pandemic.

The design of the study deals with a global policy, though implemented with variations, that affects all countries. Hence, certain limitations and noises in data are inevitable but are well accounted for in this study. In addition, lack of complete data availability is also a drawback of research of this kind. However, the study accounts for four contrasting sectors, with expected as well as found heterogeneous effects, which further strengthens the causal analysis of the effects in the ICT sector.

In conclusion, policy stringency has undoubtedly accelerated sectors like ICT, as the services of the sector was considered a surviving tool in economic terms, however, it has also led to highly disproportionate burdens on other sectors. This means the policy implications for any future crisis is clear, while broad fiscal support can help sectors remain resilient, it is not enough in an economy that consists of an array of diverse industries. Thus, for future crises solutions should be inclusive and aids should be targeted towards specific industries, ensuring optimal and equitable results.

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Appendix 1

A.1 Country-based Kalman Smoothing

To tackle the incomplete set of data, the chosen imputation method was country-based Kalman smoothing. This algorithm incorporates the time series structure of the data for each country to estimate the missing values (Harvey, 1990). Unlike popular imputation methods like mean, median which have many drawbacks when it comes to time series data, and Amelia II, which is a global imputation method (Honaker & King, 2010), the implemented Kalman approach uses country specific data to produce estimates, this ensures that the imputed values are representative of the historical pattern of each individual country, resulting in reliable and realistic predictions, especially for data with large gaps (Moritz & Bartz-Beielstein, 2017). For imputation, the Kalman Smoothing algorithm was applied to a Structural Time Series (STS) model using the function *na_kalman()* from the R package *imputeTS.*

Before the Kalman filter can be used, it is crucial that a state-space is formulated. This involves working with the observed data to break down the STS model into several underlying components such as trends, levels, and sometimes, seasonality, for a given country (Durbin & Koopman, 2012).

In the process of estimation, first the Kalman filter, which is a recursive algorithm, generates estimates for the unobserved state of the system (Kalman, 1960). The filter only estimates the state using past and present data, therefore, the more advanced Kalman smoothing is used subsequently to do backward checks throughout the entire time series, enhancing the predictions by utilizing all available data (i.e. past, present and future) (Durbin & Koopman, 2012). This ensures the unique trajectory of each country is taken into account to generate its own imputation, maintaining the consistency of the panel data.

Appendix 2

A.2 Placebo Test Results: True Effect vs. Control Country Placebos

Country	ATT	95% CI Lower	95% CI Upper
TRUE EFFECT	**107.17**	**27.71**	**157.38**
Bulgaria	2.18	-1045.18	121.80
Croatia	18.13	-782.97	251.71
Denmark	-7.88	-2740.23	264.73
Estonia	21.95	-592.13	238.94
Finland	-7.23	-979.18	140.01
Hungary	17.23	-2070.69	291.44
Iceland	14.64	-232.43	236.67
Latvia	47.81	-226.31	236.37
Lithuania	46.39	-196.01	230.75
Norway	-25.09	-2501.72	262.83
Switzerland	-21.69	-2713.64	256.55

Appendix 3

A.3 Gap Plots

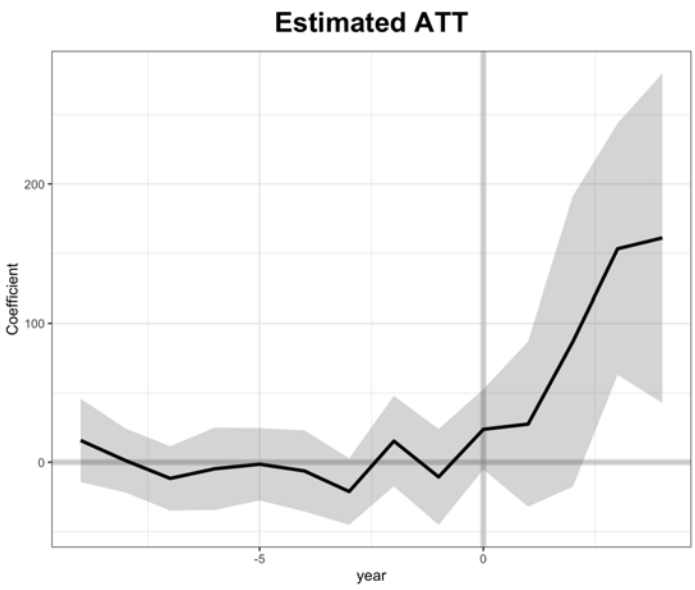

Figure A.3a: ICT

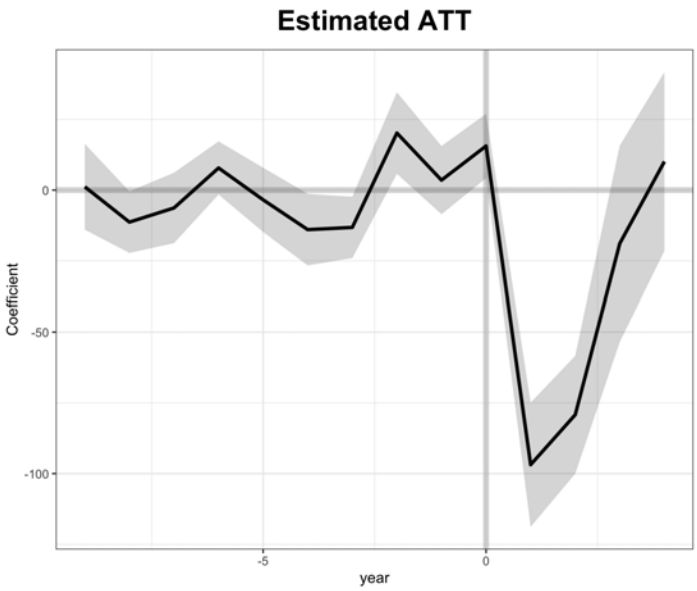

Figure A.3b: Arts, Entertainment & Recreation

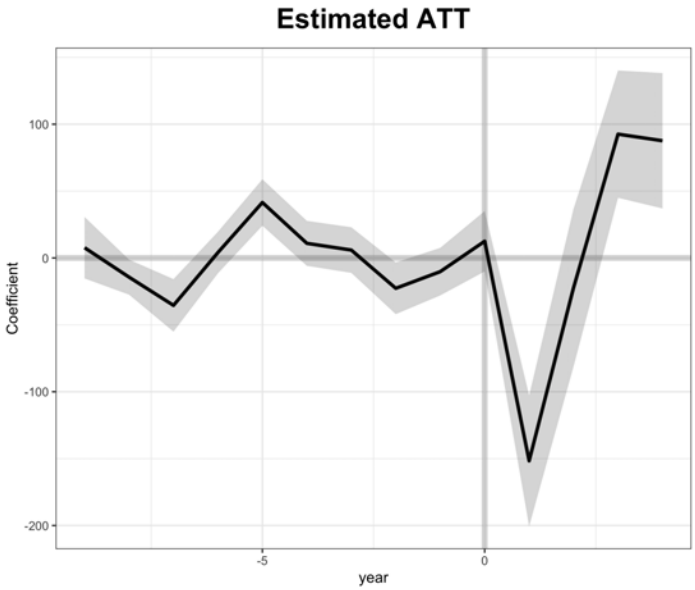

Figure A.3c: Construction

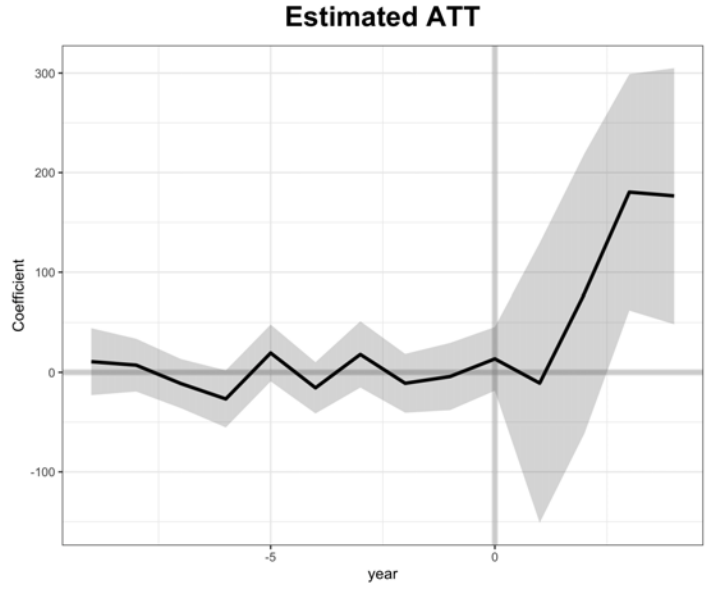

Figure A.3d: Transport & Storage

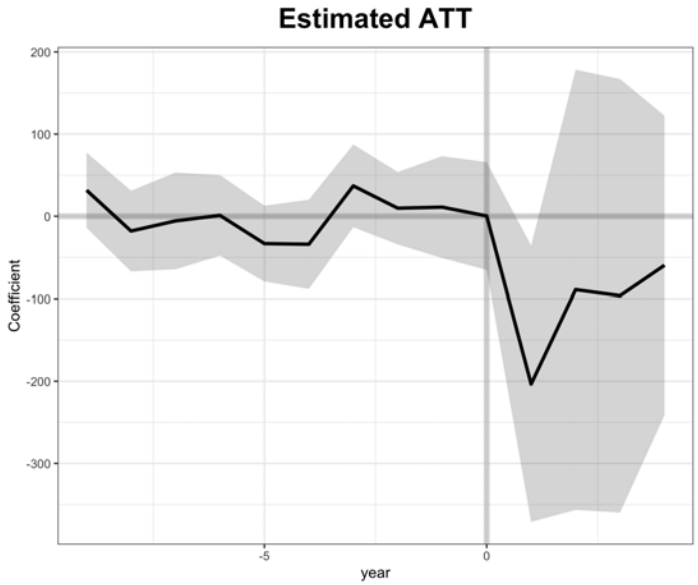

Figure A.3e: Accommodation & Food

A.4 Factor Loading

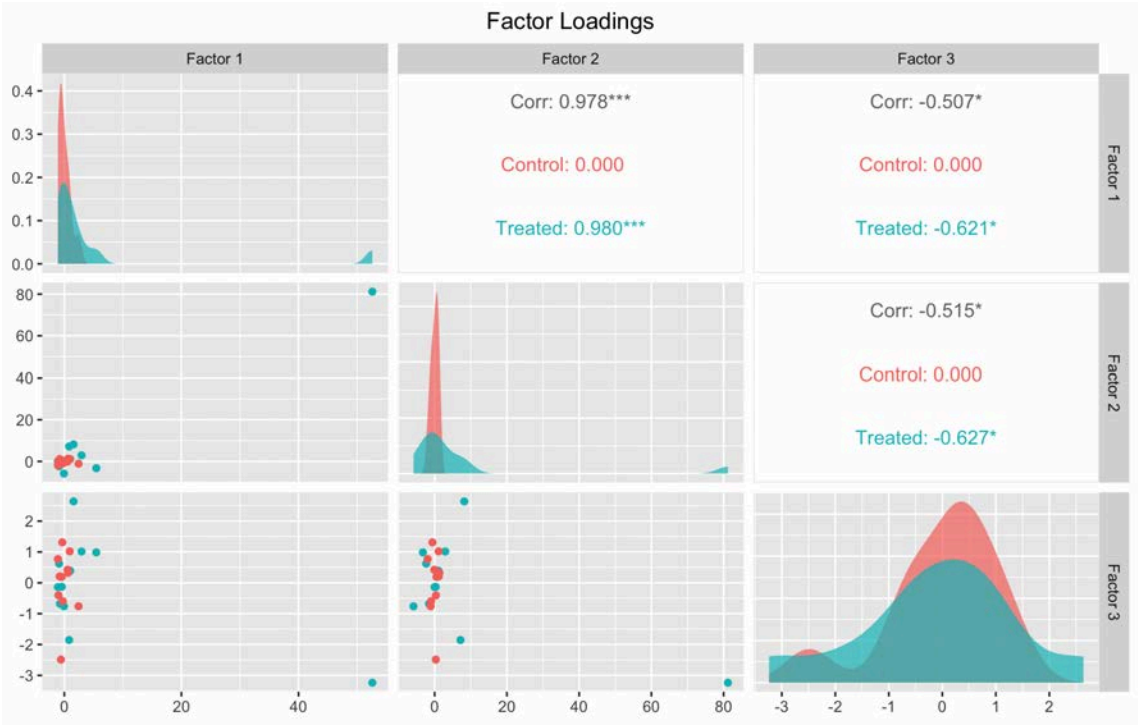

Figure A.4a: Information and Communication Factor Loading

The plot shows group separation, with treated countries exhibiting a very similar response to unobserved shocks. Here, the strong correlation between Factor 1 and Factor 2 (0.98***), indicates that a single underlying factor is driving the course. This is likely due to the increased demand for digitally done work that was disproportionately experienced in the treated countries during the pandemic relative to the control. Moreover, the cluster of these treated countries along these common factors further validates grouping these countries together to study the effects of lockdown policy.

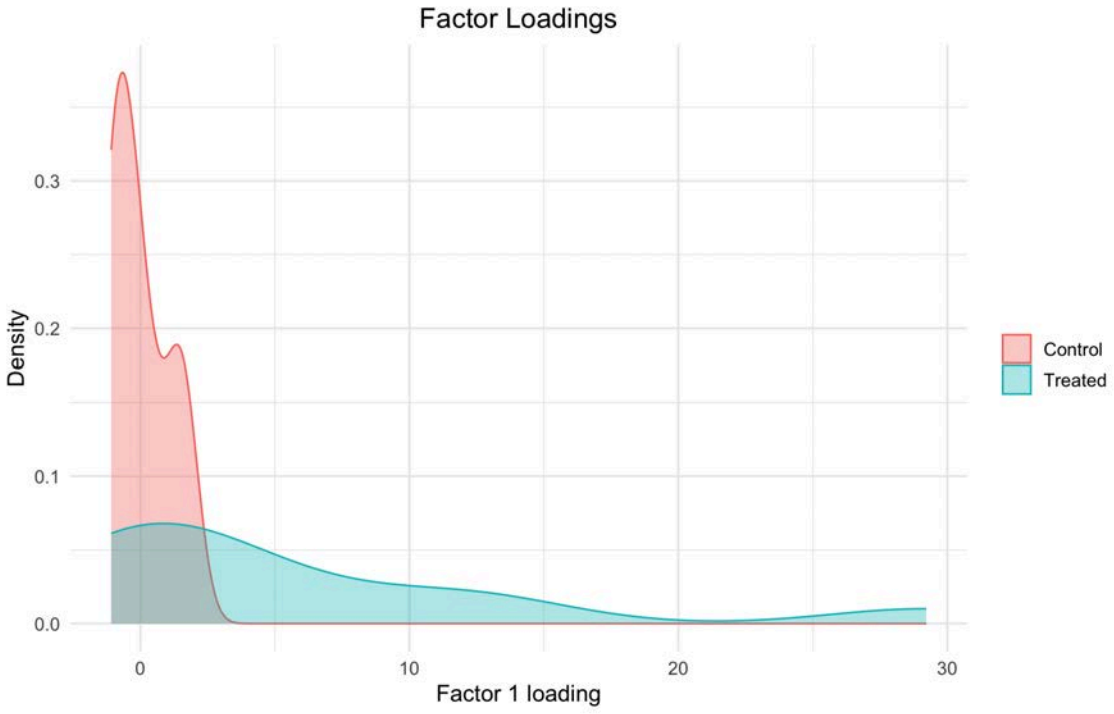

Figure A.4b: Arts, Entertainment & Recreation Factor Loading

The Arts, Entertainment & Recreation sector is a one-dimensional split with treated countries being concentrated on the positive side of Factor 1, whereas control countries clustered around the negative side. This means that countries with high stringency responded differently to the same pandemic shock compared to countries with low stringency. This contrast highlights the

lockdown policy as the primary determinant of the sector's fate, hence, justifying the measured negative effect on employment.

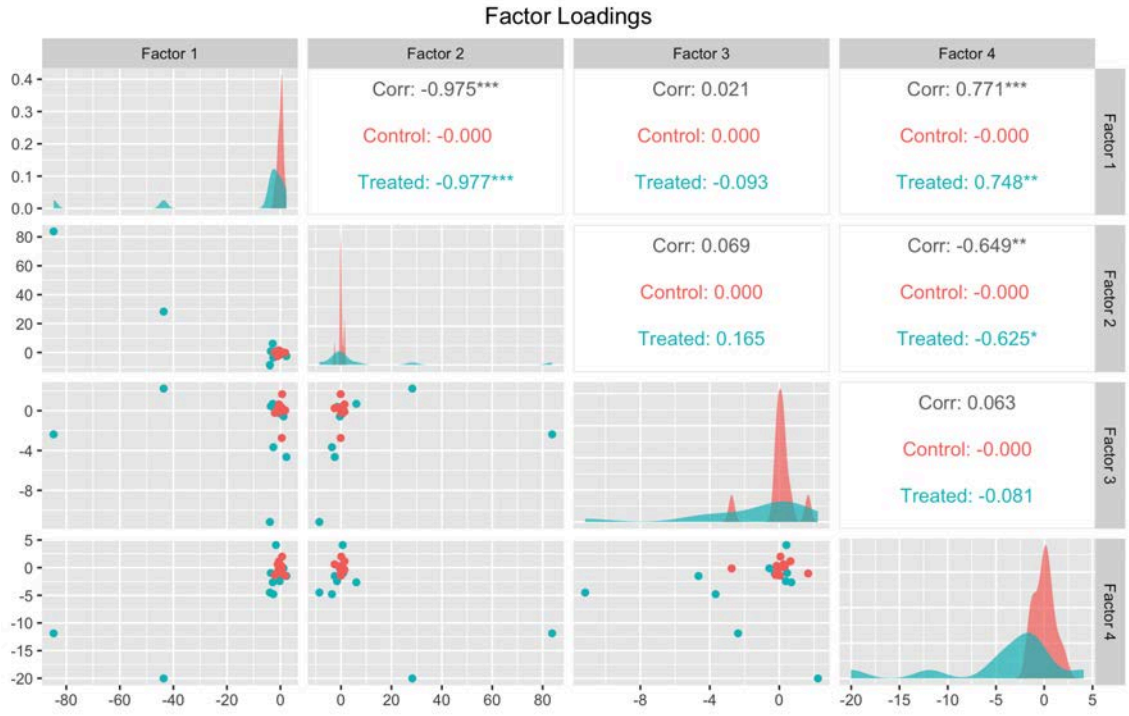

Figure A.4c: Transport & Storage Factor Loading

The Transport & Storage factor analysis shows the treated countries were highly responsive along two latent dimensions, with a lower score on Factor 2 (-0.98***) and a higher one on Factor 4 (0.75**). These opposing patterns suggest that there are different elements (i.e. shared logistics boom and/or the collapse in passenger transport) resulting in internal conflict. This explains why the sector's overall effect was positive but statistically insignificant.

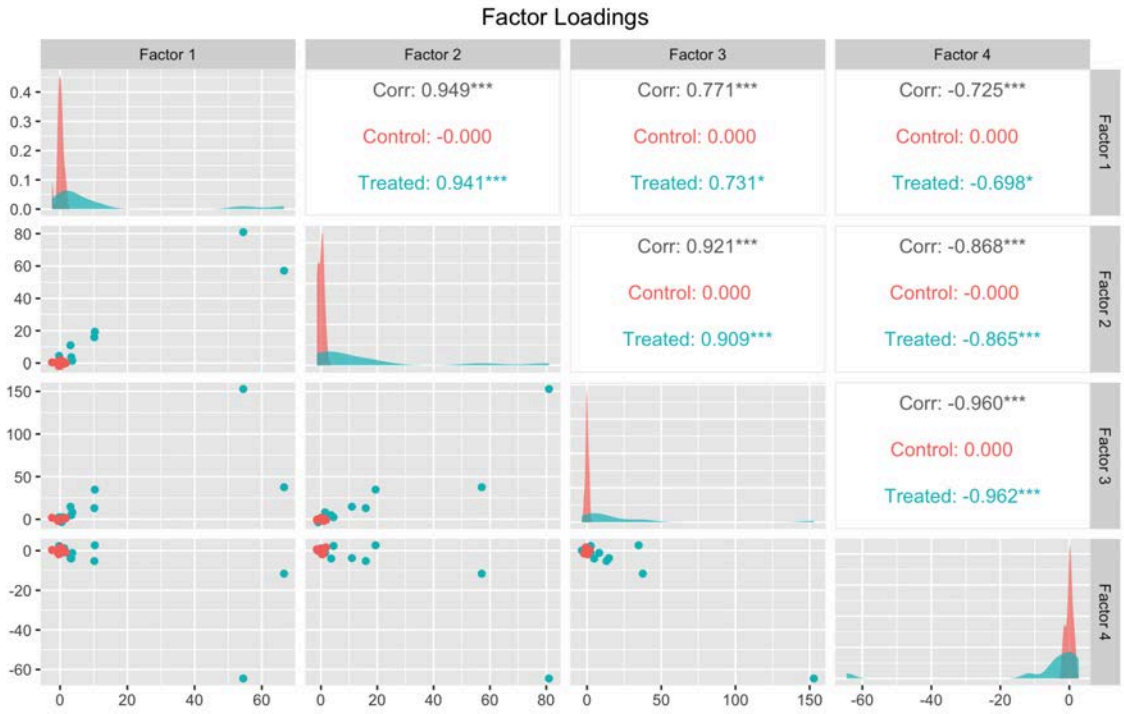

Figure A.4d: Accommodation & Food Factor Loading

The factor analysis shows a mixed pattern, with higher scores on Factor 2 (0.94***) and Factor 3 (0.91***), whereas Factor 4 scores much lower (-0.96***). This likely reflects the complexity of the events in the sector, where tourism dependent countries experienced a heightened level of the same shock that hit all other countries. The factor loading does not just illustrate a dual experience but explains the statistical uncertainty in the results.

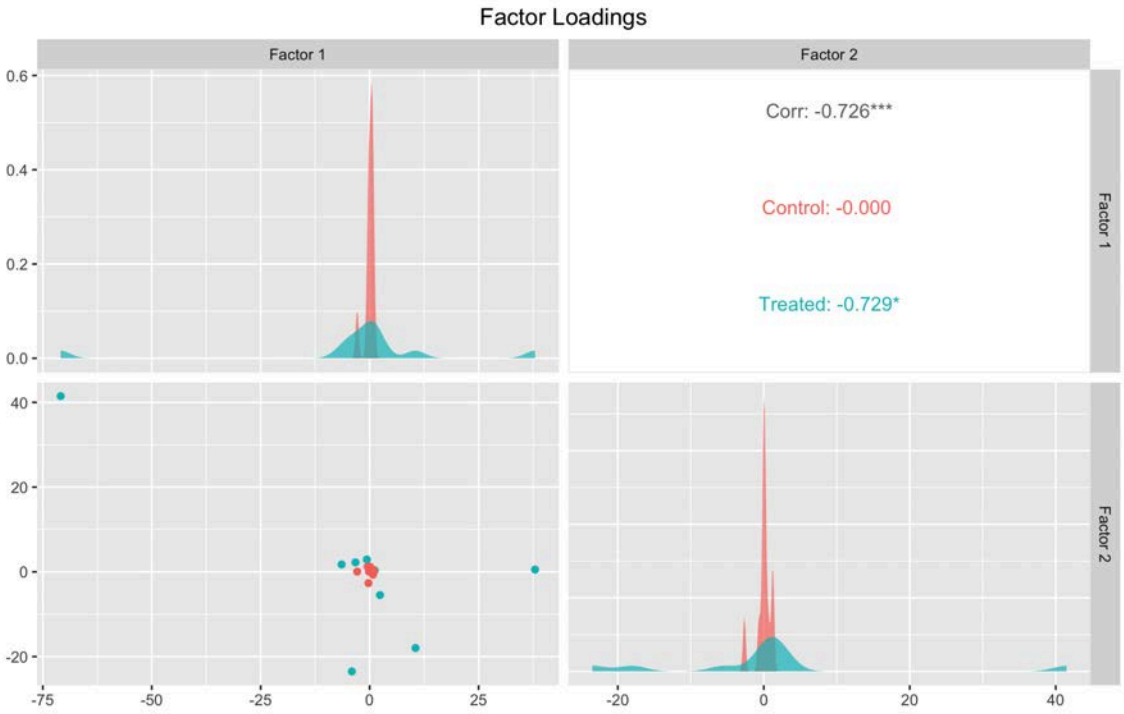

Figure A.4e: Construction Factor Loading

The plot shows that the two factors are strongly correlated (-0.73***) and have a significant overlap between the treated and control countries, Factor 2 (0.73*), a slightly lower score, and an almost complete overlap on Factor 1. This suggests that the Construction sector across both high and low stringent countries responded in a similar manner to the pandemic shocks. Furthermore, supports the sector's status of being 'essential' and the v-shaped recovery captured by the ATT.