

**The impact of technological progress on sectoral carbon emissions: Does it differ across country's income groups?**

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# Overview of today's presentation



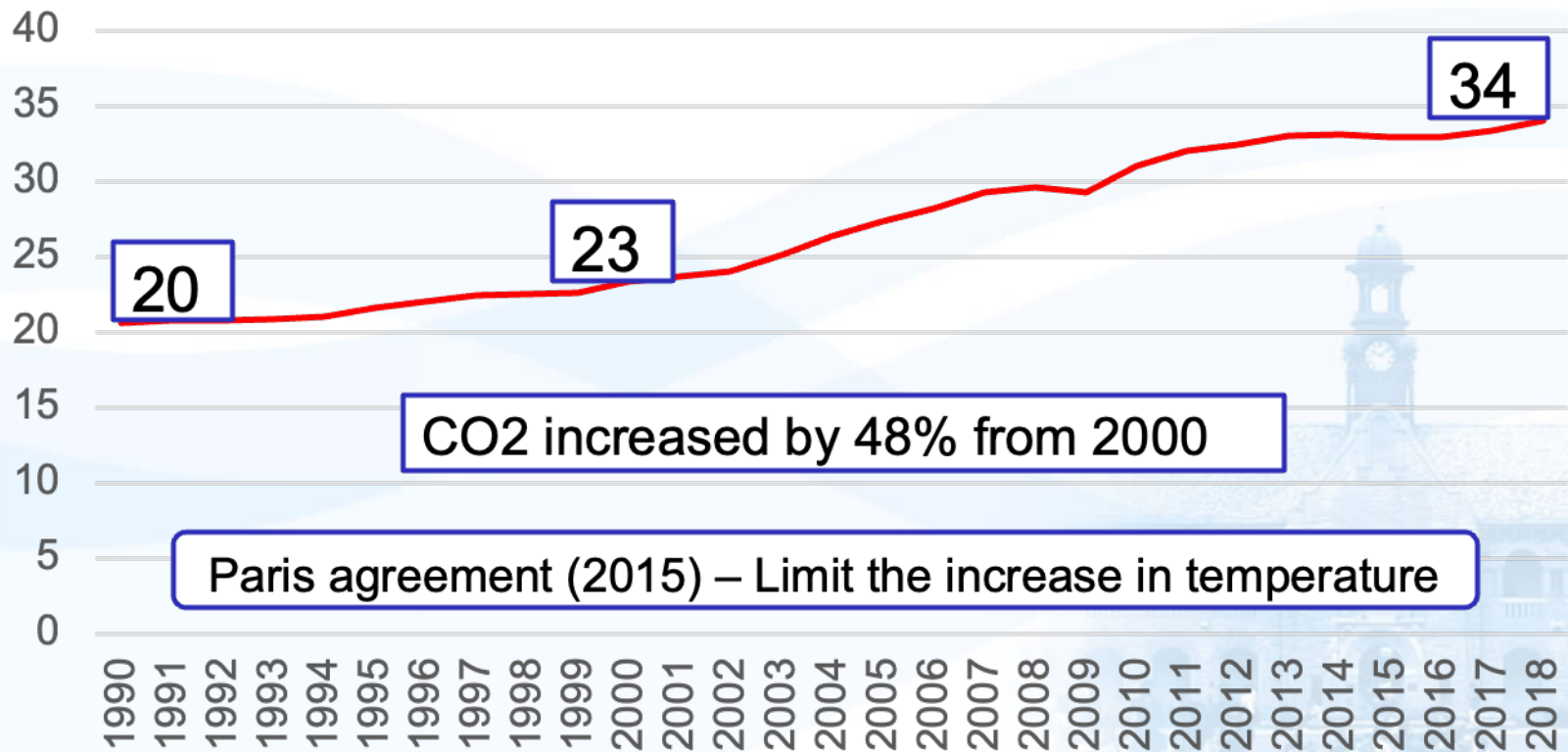
1. Context
2. Research Problem
3. Literature Review
4. Data and Methodology
5. Results





# 1. Context

## World CO2 emissions (billions of tons)

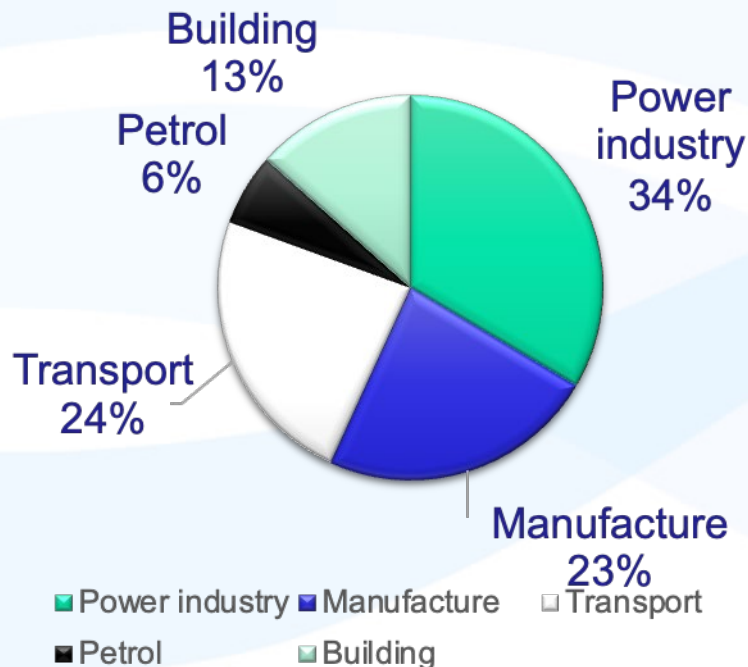


Data source: WDI (2020)



# 1. Context

## Full sample/emissions per sector: 1999-2018



## Solutions to climate change:

- Renewable energy
- Sustainable transportation
- Compliance to environmental laws
- Recycling and waste management
- Forest protection and reforestation
- **Technological progress**



## 2. Research Problem

*What is the impact of **aggregate** technology and **green** technology on sectoral CO2 emissions? Does this impact differ across countries' income groups?*

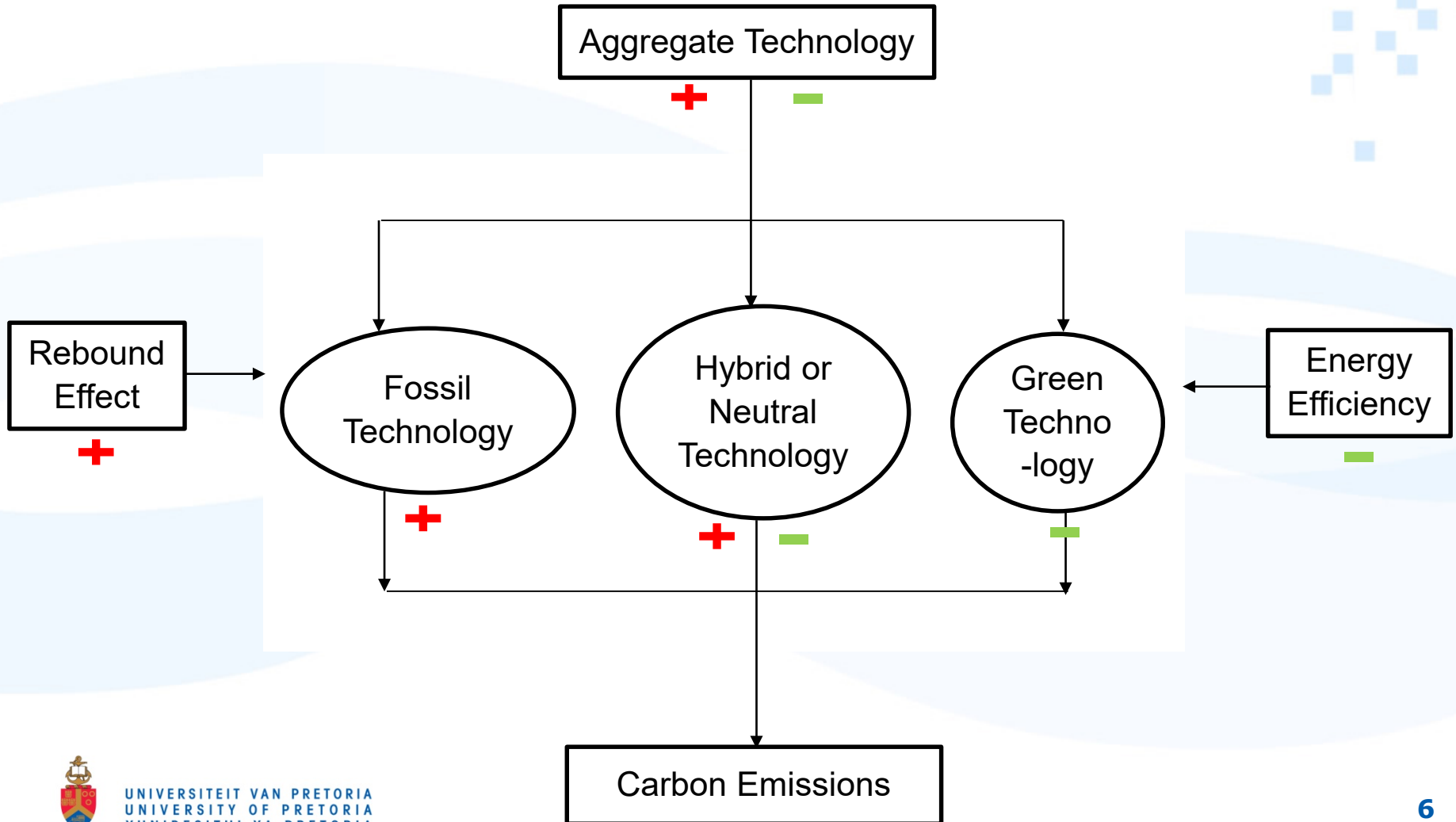
### Why is it important to investigate this question?

- The role of technology in the climate change crisis
- Looking at the climate change problem from different energy sectors perspective (power, manufacture, transport, petrol, and building)
- Effect of technology may be different in each sector due to differences in production process, financial capacities to induce and spread innovations, their vulnerability to the rebound effect, compliance to strict environmental regulations.





# Diagram: Technology and CO2 emissions





### 3. Literature Review

- Erdogan et al. (2020), impact of the innovation process on sectoral CO2 emissions for 14 countries in the G20, from 1991 to 2017.
- Erdogan (2021), the effect of technology on carbon emissions from the building sector in the BRICS countries, from 1992 and 2018.
- Sedat Alatas (2021), impact of green technology on carbon emissions from the transport sector in 15 European countries, from 1977 to 2015.
- Robaina and Neves (2021) identify the main factors that explain variations of carbon emissions intensity in the EU transport sector
- Isik, Ari, and Sarica (2021) identify drivers of carbon emissions in the Turkish power sector.

### 3. Literature Review - Contribution of this study



- Analysing the relationship between carbon emissions, and **aggregate and green** technology in more than one sector.
- Using principal component analysis, we construct an index of aggregate technology from four usual indicators of technological progress (patents applications, R&D expenditure, ICT, and science and technology publications)
- Analysing the relationship between **sectoral** carbon emissions and technology in a full sample of 45 countries and in **3 different income groups**.

## 4. Data and Methodology



### 4.1 Data

- This study covers 45 economies constituted of 15 high-income, 15 upper-middle-income, and 15 lower-middle-income countries. The Period is 20 years, from 1999 to 2018. In 2016, the 45 economies selected in this study represented 90 per cent of global GDP, and 88 per cent of global CO<sub>2</sub> emissions.
- Most of the data used in this study is derived from the World Development Indicators (World Bank, 2019).
- Data on sectoral CO<sub>2</sub> emissions comes from Emissions Database for Global Atmospheric Research (EDGAR, 2021).

## 4.1 Data



- Aggregate technology index

$$\mathbf{Tech\_index}_{it} = f(\mathbf{ICT}_{it}, \mathbf{PAT}_{it}, \mathbf{RD}_{it}, \mathbf{Scien\_tech}_{it}, \mathbf{Educ}_{it}, \mathbf{MVA}_{it})$$

$ICT_{it}$  internet users per 100 people,  $PAT_{it}$ : number of patent applications per 1000 people,  $RD_{it}$ : Research & Development expenditure as a percentage of GDP,  $Scien\_tech_{it}$ : science and technology publication per 1000 of people,  $Educ_{it}$ : enrolment ratio in tertiary education,  $MVA_{it}$ : manufacture value added as a percentage of GDP.



## 4.1 Data

- Aggregate Technology Index
  - Correlation Matrix

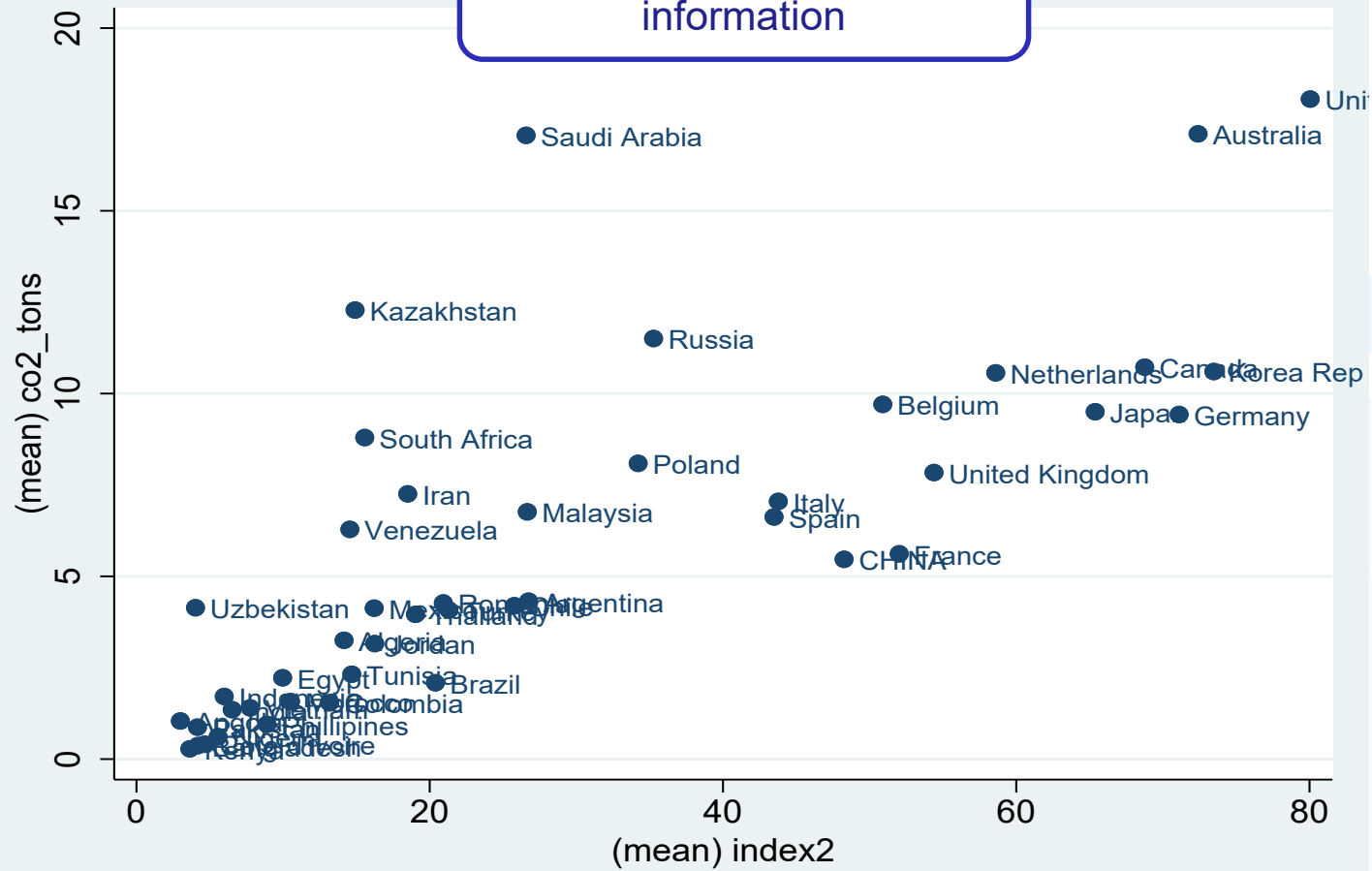
	$ICT_{it}$	$PAT_{it}$	$RD_{it}$	$Scien\_tech_{it}$	$Educ_{it}$	$MVA_{it}$
$ICT_{it}$	1					
$PAT_{it}$	0.5916	1				
$RD_{it}$	0.5236	0.7863	1			
$Scien\_tech_{it}$	0.6196	0.8552	0.8872	1		
$Educ_{it}$	0.6757	0.6101	0.6246	0.6751	1	
$MVA_{it}$	0.5299	0.5653	0.7242	0.6490	0.7136	1





## 4.1 Data – Aggregate Technology Index

First PCA containing 76% of information





## 4.2 Methodology

Dynamic panel model (Kais and Sami, 2016; Zhang et al. 2017).

$$\ln SCE_{it} = \beta_0 + \beta_1 \ln SCE_{it-1} + \beta_2 \ln URB_{it} + \beta_3 \ln GDP_{it} + \beta_4 \ln TECH_{it} + \beta_5 FIN\_DEV_{it} + \beta_6 GDP_{it}^2 + u_i + v_{it}$$

( $SCE_{it}$ ) sectoral carbon emissions. ( $URB_{it}$ ) urbanization. ( $GDP_{it}$ ) GDP per capita, ( $TECH_{it}$ ) aggregate and green technology. ( $FIN\_DEV_{it}$ ) financial development. ( $GDP_{it}^2$ ) for the Environmental Kuznets Curve (EKC). ( $TECH_{it}$ ) aggregate technology or green technology.



## 4. Data and Methodology

The main equation will be divided into 5 empirical models:

- $\ln Power_{it} = \ln(Power_{it-1})\delta + \ln(TECH)_{it}\beta + X'_{it}\rho + u_i + v_{i,t}$
- $\ln Manuf_{it} = \ln(Manuf_{it-1})\delta + \ln(TECH)_{it}\beta + X'_{it}\rho + u_i + v_{i,t}$
- $\ln transport_{it} = \ln(Transp_{it-1})\delta + \ln(TECH)_{it}\beta + X'_{it}\rho + u_i + v_{i,t}$
- $\ln Petrol_{it} = \ln(Petrol_{it-1})\delta + \ln(TECH)_{it}\beta + X'_{it}\rho + u_i + v_{i,t}$
- $\ln building_{it} = \ln(Building_{it-1})\delta + \ln(TECH)_{it}\beta + X'_{it}\rho + u_i + v_{i,t}$





# Methodology

## Three Econometric techniques

- Two-steps DIF-GMM model: Nickel bias,  $T < 20$  years (Judson & Owen, 1999).
- Fixed model with robust standard errors: Account for cross sectional heterogeneity (Baltagi, 2008).
- Feasible generalized Least Square model (FGLS): Account for cross sectional dependence, heteroskedasticity, and serial correlation (Bai, Hoon Choi, & Liao, 2021).



# 5. Empirical Results ( Aggregate Technology)

## Two step DIF-GMM



	Power	Manu	Transp	Petrol	Building		Power	Manuf	Transp	Petrol	Building
	Full sample						High-income countries				
<b>TECH<sub>it</sub></b>	.011*** (4.26)	.003*** (4.32)	.002** (2.30)	.004** (2.18)	-.0004 (-0.43)		.0029 (0.43)	-.003** (2.48)	.0006 (1.13)	.0109* (1.95)	-.0044** (-2.62)
GDP <sub>it</sub>	1.89*** (3.16)	1.14*** (4.44)	1.36** (2.59)	1.13** (2.35)	1.45*** (3.84)		-.0791 (-0.24)	-.0444 (-0.77)	.5188** (2.42)	-.2884 (-0.83)	.1242** (2.49)
GDP <sub>it</sub> <sup>2</sup>	-.10*** (-3.20)	-.05*** (-4.11)	-.0479 (-1.60)	-.0537 (-1.55)	-.0593** (-2.93)						
Turn. P	17 994	19 190	-	-	24 451						
	Upper-middle income countries						Lower-middle income countries				
<b>TECH<sub>it</sub></b>	.0183** (2.74)	-.0025 (-0.23)	.0163* (1.73)	-.0052 (-0.52)	.0024 (0.31)		.0231** (2.69)	.0142* (1.86)	.0266** (2.51)	.0042 (0.60)	.0118* (1.73)




## 5. Empirical Results (Aggregate Technology)



- Full sample results: aggregate technology increases carbon emissions in all sectors, except the building sector.
- Subsample indicate that, generally, aggregate technology is positively associated with carbon emissions across sectors in upper middle income and lower-middle-income countries, however, it is negatively related to carbon emissions from the manufacturing and building sector in high-income countries.



## 5. Empirical Results (Aggregate Technology)

- High income countries
  - Technology reduces CO2 in manufacture  Building sector 
  - Manufacturing: energy mix, regulations, energy savings technics and technologies
  - Building: smart cities, efficient technologies, energy efficiency investment in building (USD 130 billions in 2020) (IEA, 2021)
- Other key drivers of carbon emissions
- Generally, GDP per capita, urbanization, and financial development increase CO2 in the full sample and in subsamples.

## 5. Empirical Results (Aggregate Technology)



- Environmental Kuznets curve (EKC) in the full sample
- EKC is not found in transport and petrol sector: The petrol sector is primarily a carbon-intensive sector by its nature, and the transport sector greatly relies on the consumer's individual choice on the type of vehicle to purchase (electric cars are still expensive).





## 5. Empirical Results (Aggregate Technology)

	Power	Manu	Transp	Petrol	Building		Power	Manuf	Transp	Petrol	Building
	Full sample						High-income countries				
<b>TECH<sub>it</sub></b>	<b>-.14***</b> (-7.22)	<b>-.18***</b> (-9.94)	<b>-.08***</b> (-8.04)	<b>-.03</b> (-0.37)	<b>-.16***</b> (-12.88)		<b>-.179***</b> (-2.96)	<b>-.246**</b> (-4.56)	<b>.085*</b> (-1.97)	<b>-.035</b> (-0.55)	<b>-.113***</b> (-4.50)
	Upper-middle income countries						Lower-middle income countries				
<b>TECH<sub>it</sub></b>	<b>.0372</b> (0.25)	<b>-.135*</b> (-1.77)	<b>-.069*</b> (-1.84)	<b>-.0265</b> (0.22)	<b>-.222**</b> (-2.58)		<b>.4824</b> (0.86)	<b>-1.13**</b> (-2.87)	<b>-.292*</b> (-1.73)	<b>.4512</b> (0.79)	<b>-.217*</b> (-1.01)





## Concluding Thoughts

- Technological progress remains a fundamental tool against climate change.
- Efforts made so far to decarbonize technology are not enough. Efforts must be accelerated and multiplied.
- The Private sector which owns most companies in the manufacturing and Building sector plays a critical role in the energy transition.
- Technology transfer and spill over effect from manufacturing and building sector to other economic sectors.
- Environmental regulations is critical
- Feedback?



**Thank you for your attention!**

