



Is the Adoption of Electric Vehicles (EVs) and Solar Photovoltaics (PVs) Interdependent or Independent?

An Integrated EVs-PVs Modeling Framework

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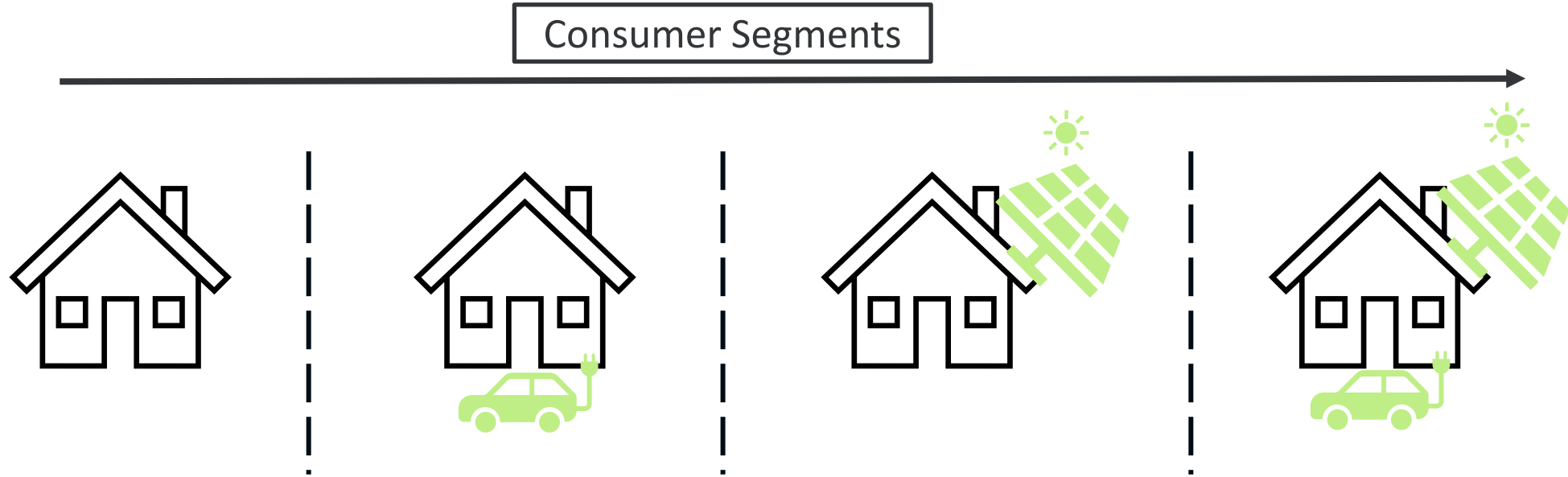
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Introduction

- Transport and residential energy consumption account for more than **one-half** of the overall energy consumption in the United States
- With **EV adoption** on the **rise**, the source of powering vehicle is gradually shifting away from **gas pumps** to the **electrical outlet**
- PVs offer a viable **carbon free source of electricity** that can support the growing demand as well as decarbonization effort in **power and transport sectors**
- However, both these technologies are **incentivized and deployed disjointly** without considering the potential interactions

Pathways to Decarbonize Household Energy Footprint



Research Questions

Is the adoption behavior of EV and PV **interdependent or independent**?

What are the role of **attitudes, values, and perceptions** in adoption patterns of EVs and PVs?

Who are **adopting** EVs and/or PVs?

Literature on EV, and PV Ownership

Electric Vehicles (EVs)

- EVs are owned by individuals who are **older**, have higher income, and reside in **urban areas**
- EV owners prefer **home** charging followed by **work and public** charging locations
- In the U.S., there is a proposed **federal tax credit** of up to \$4,000 on used EVs and \$7,500 on new EVs; in India, **tax exemptions** are provided to EV owners

Solar Photovoltaics (PVs)

- PVs are owned by individuals who are **middle-aged**, have higher income, and reside in **rural areas**
- Charging EVs through **residential solar** can nearly double the cost savings compared to dynamic **electric tariff** strategies
- In the U.S., 30 percent of total PV installation cost can be claimed as a **federal tax credit**; in India, a 40 percent **subsidy** is provided to install solar panels

Integrated Assessment of EVs and PVs

- A study from **Swiss residents** reported significant increase in the intention to adopt EVs when consumers were offered charging services **bundled with EV purchase**
- A survey from **German consumers** reported that willingness to buy community solar panels and electric vehicles was higher than buying an **EV alone**
- Integrating **photovoltaics in electric vehicles** was found to cover up to 35 percent of driving range per year
- Sheperoa et al (2018) concluded that there is a need to develop advanced **spatio-temporal** and integrated EV-PV modeling frameworks

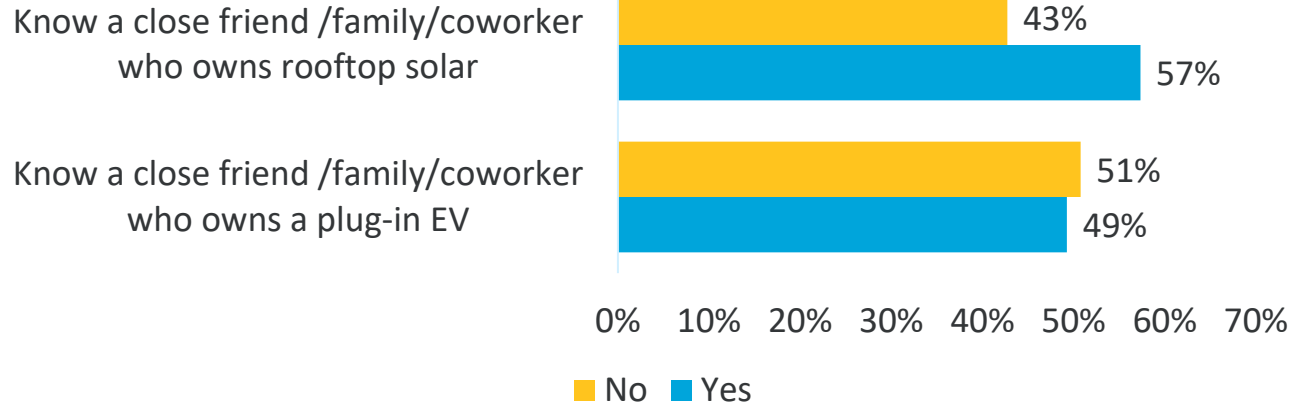
A scan of **EV, PV, and EV-PV literature** reveals a clear gap re: absence of a joint adoption modeling framework that explicitly considers the **inter-relationship** in **adoption behaviors** of EVs and PVs

Dataset

- **WholeTraveler Transport Behavior Study Survey**
 - Year: 2018
 - Sample: San Francisco Bay Area
 - Sample size: 869 respondents
 - Exogenous Variables
 - (a) Socio-demographic characteristics
 - (b) Travel and location attributes
 - (b) Attitudes/perceptions towards sustainable technologies
 - Endogenous Variables
 - (a) Own a plug-in electric vehicle(s)
 - (b) Own a rooftop solar panel(s)

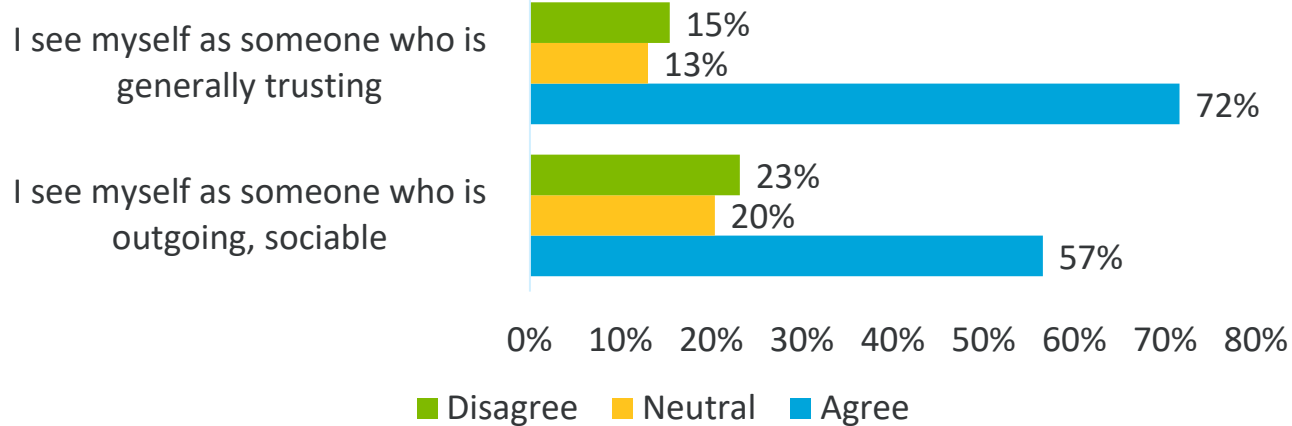
Latent Attitudinal Constructs

Technology Cognizance



- Greater **familiarity** with Solar Photovoltaics (57 percent) compared to Electric vehicles

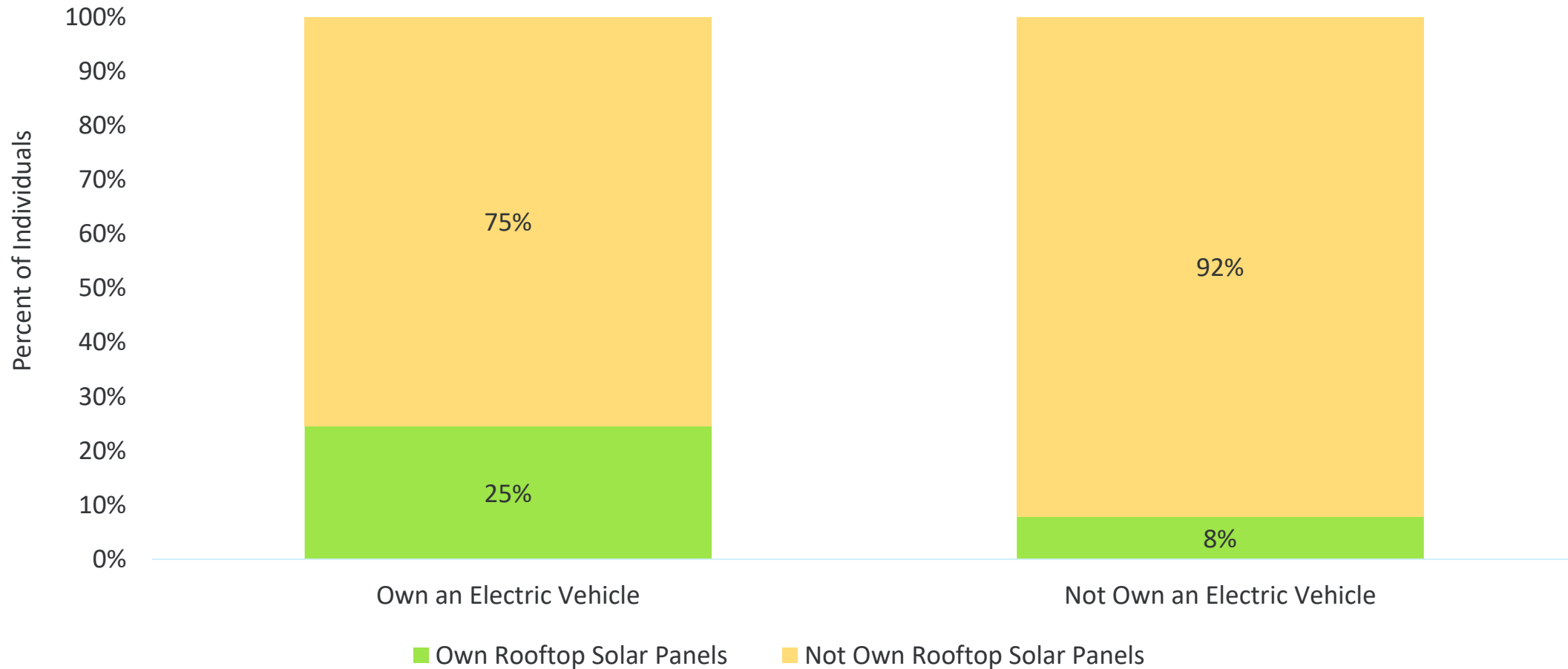
Extrovert Personality Traits



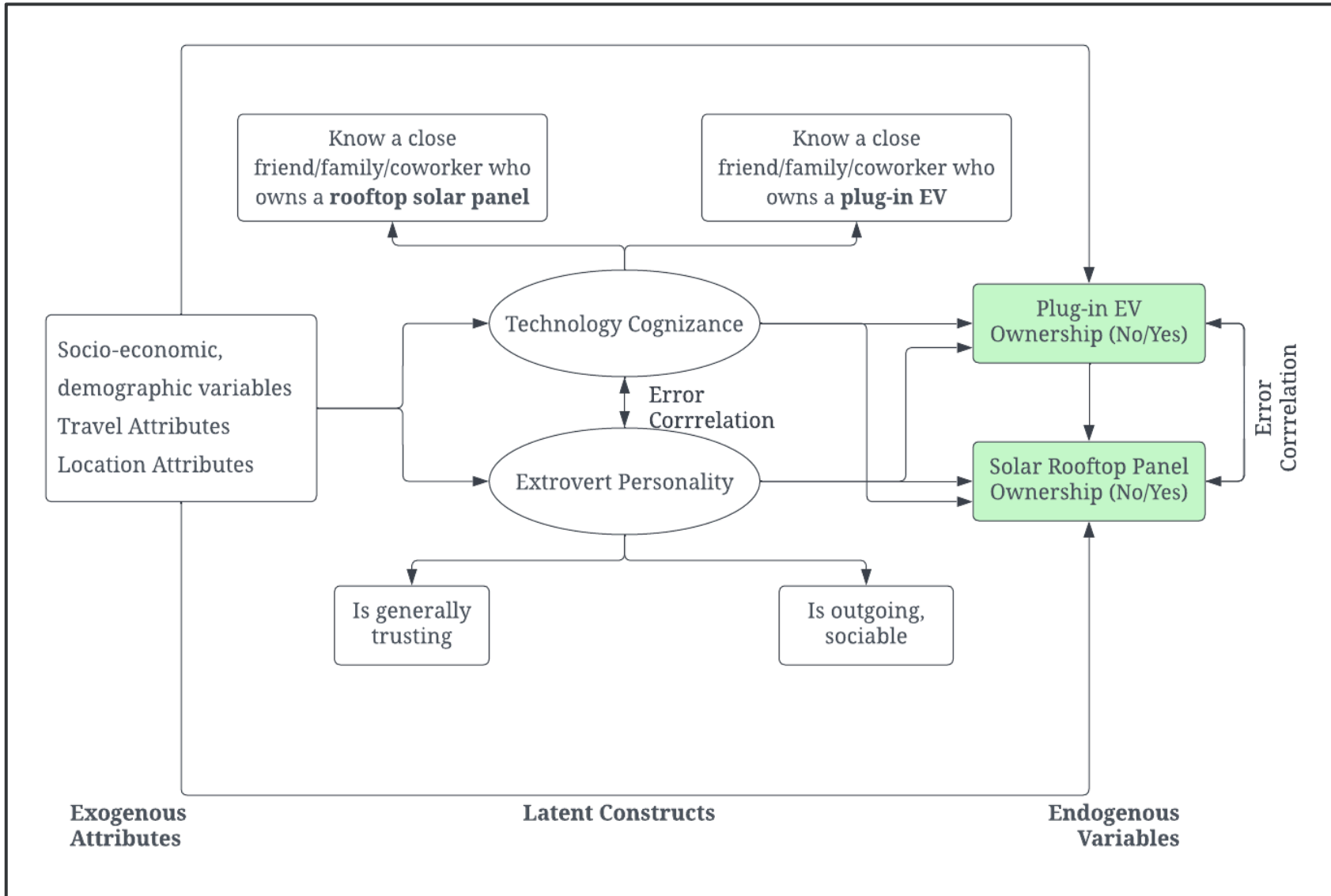
- About 70 percent of the respondents identified themselves as **generally trusting**, while 57 percent agreed that they are **outgoing and social**

Relationship Among Endogenous Variables

25 percent of EV owners also own a rooftop solar panels, while only 8 percent of the non-EV owners, own PVs – indicating that **EV and PV ownerships might be correlated**



Integrated EV-PV Modeling Framework



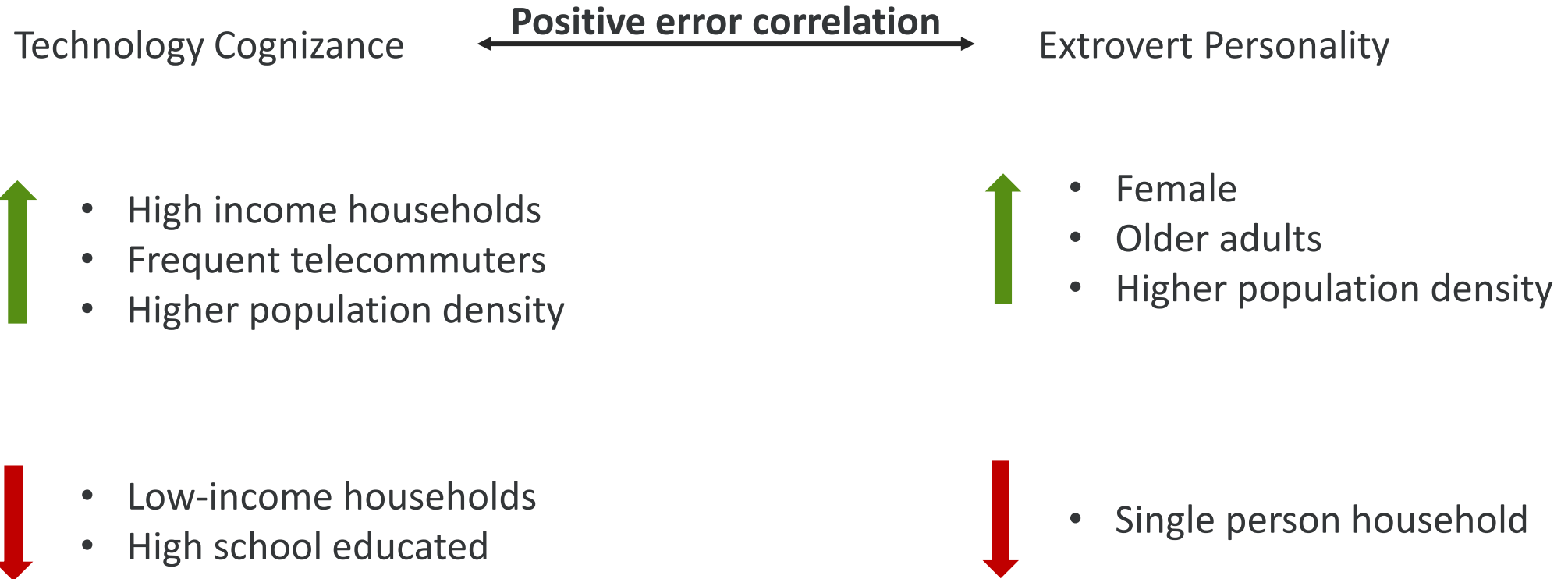
Measurement Model for **Latent Psychological Factors**

$$z_j^* = w_j \alpha_j + \eta_j$$

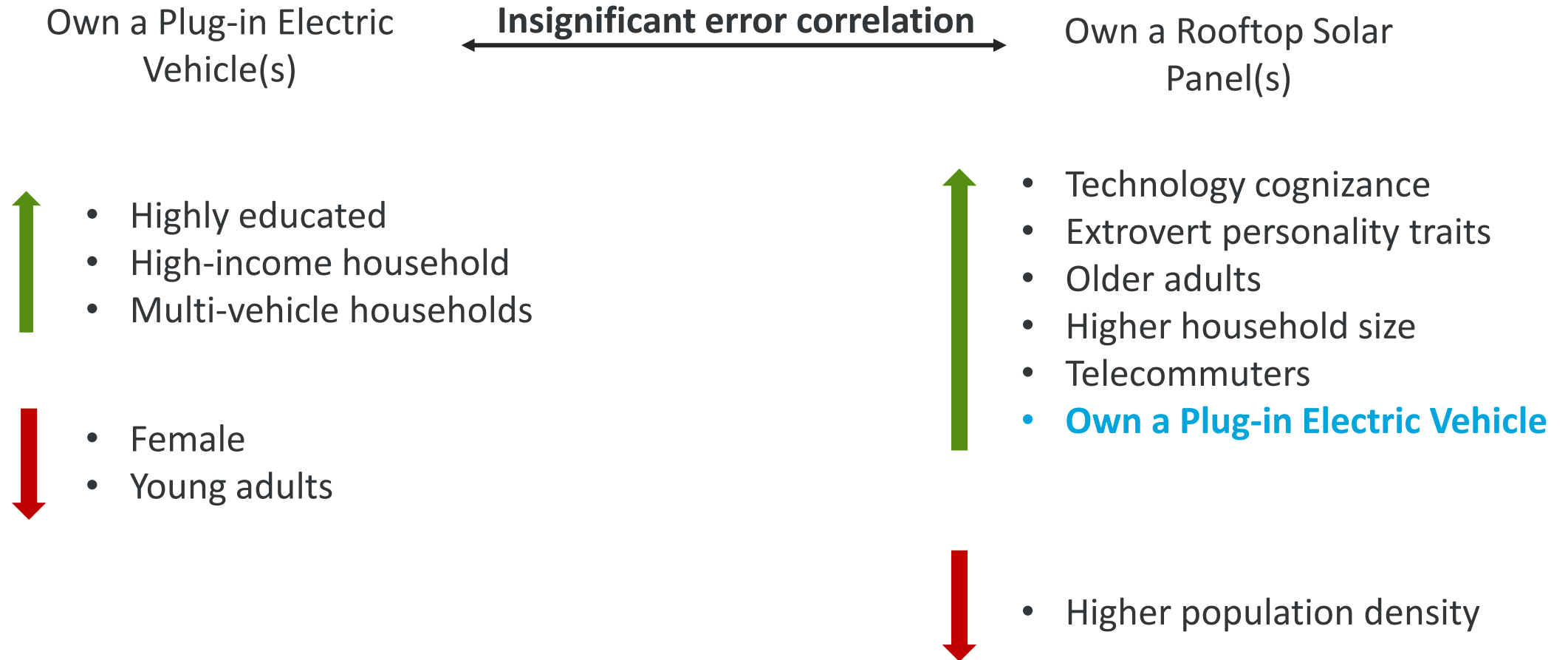
Structural Equation Model for **Observed Endogenous Variables**

$$y_i = x_i \beta_i + z^* \gamma_i + \varepsilon_i$$

What Factors Influence Latent Attitudinal Constructs?



What Factors Influence EV-PV Adoption?



Discussion

*Is the adoption behavior of EV and PV **Interdependent or Independent**?*

Owning EVs had a **positive and statistically significant** impact on owning PVs (EV → PV), suggesting **interdependency**

*What are the role of **attitudes, values, and perceptions** in adoption of EVs and PVs?*

Those who are **technology cognizant** are less likely to own EVs but more likely to own PVs

*Who are **adopting** EVs and/or PVs?*

Younger individuals are less likely to **own EVs**, while **older adults** are more likely to **own PVs**

Highly educated and higher income individuals are more likely to own EVs, while **larger households** are more likely to own PVs

Telecommuters are more likely to own PVs, while individuals who reside in densely populated areas are less likely to own PVs

Study Conclusions and Implications

- This research effort presents an **integrated model system** that explicitly accounts for the **interdependencies** in the adoption of EVs and PVs
- Latent attitudinal constructs are influenced by socio-demographic characteristics, travel attributes, and location information
- Major finding of this research effort is that ***‘owning an EV had a positive and statistically significant impact on owning PVs’***
- The integrated EV-PV modeling framework can help strategize long-term planning investments that drive ***‘bundled adoption’*** of sustainable technologies
- The study highlights the need to bring **‘transport and building energy consumption’** research into a ***single integrated structure***

Thank you!

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Direction of Future Research

- The dataset used in this analysis is nearly **four-years old**; a lot has transpired over the past four-years, including experience of a pandemic, economic hardship, supply chain issues, soaring gas prices, increased EV sales, and now recently updated federal incentives for both PVs and EVs
- More data are needed that capture **individual attitudes, perceptions, and subjective norms** to unravel the subliminal motivations behind adoption of EVs and PVs
- Individuals' reaction to **bundled incentives** for EV and PV ownership should be elicited through surveys to accurately **quantify incremental adoption** such incentives can bring about