

# AI-Generated Production Networks: Construction, Validation and Measurement Concepts

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Let me begin with a digression

***Inference will meet retrieval***

# Illustrating some concepts

## 1. **Listen to some natural text**

Who can still remember the first words I used at the start of this lecture?

## 2. **What did you have for breakfast**

Distinguishing between what is relevant and not.

## 3. **What is learning?**

Connecting dots.

## 4. **What do humans need look like in the post materialistic society?**

Attention is all you need or alternatives to human flourishing.

## 5. **What are we actually doing?**

Connecting dots.

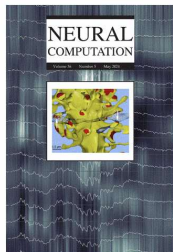
# Of bits and bytes

| object size | legacy  |
|-------------|---------|
| 1           | 1 bytes |
| 1024        | 1 Kb    |
| $1024^2$    | 1 Mb    |
| $1024^3$    | 1 Gb    |
| $1024^4$    | 1 Tb    |
| $1024^5$    | 1 Pb    |

# How about the human brain?

Volume 36, Issue 5

May 2024



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April 23 2024

## Synaptic Information Storage Capacity Measured With Information Theory 🔑

In Special Collection: CogNet

Mohammad Samavat ✉, Thomas M. Bartol, Kristen M. Harris ✉, Terrence J. Sejnowski ✉



> Author and Article Information

*Neural Computation* (2024) 36 (5): 781–802.

[https://doi.org/10.1162/neco\\_a\\_01659](https://doi.org/10.1162/neco_a_01659) Article history 🕒

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## Abstract

Variation in the strength of synapses can be quantified by measuring the anatomical properties of synapses. Quantifying precision of synaptic plasticity is fundamental to understanding information storage and retrieval in neural circuits. Synapses from the same axon onto the same dendrite have a common history of coactivation, making them ideal candidates for determining the precision of synaptic plasticity based on the similarity of their physical dimensions. Here, the precision and amount of information stored in synapse dimensions were quantified with Shannon information theory, expanding prior analysis that used signal detection theory (Bartol et al., 2015). The two methods were compared using dendritic spine head volumes in the middle of the stratum radiatum of hippocampal area CA1 as well-defined measures of synaptic strength. Information theory delineated the number of distinguishable synaptic strengths based on nonoverlapping bins of dendritic spine head volumes. Shannon entropy was applied to measure synaptic information storage capacity (SISC) and resulted in a lower bound of 4.1 bits and upper bound of 4.59 bits of information based on 24 distinguishable sizes. We further compared the distribution of distinguishable sizes and a uniform distribution using Kullback-Leibler divergence and discovered that there was a nearly uniform distribution of spine head volumes across the sizes, suggesting optimal use of the distinguishable values. Thus, SISC provides a new analytical measure that can be generalized to probe synaptic strengths and capacity for plasticity

# Estimated Synaptic Storage Capacity

- ▶ Number of synapses in the human brain:  
 $\sim 10^{14}$  (100 trillion)
- ▶ Synaptic information storage capacity (SISC) per synapse:  
4.1 to 4.6 bits (Samavat et al., 2024)
- ▶ **Total brain capacity:**

$$(4.1 \text{ to } 4.6) \times 10^{14} \text{ bits} \approx 51 - 57 \text{ TB}$$

- ▶ *Assuming 8 bits = 1 byte and converting to terabytes*

## Comparison With Other Data Sources

| Data Source                           | Size Estimate    |
|---------------------------------------|------------------|
| Human brain (estimated)               | 51–57 TB         |
| All of Wikipedia (text only)          | ~ 20 GB          |
| Entire English Wikipedia (with media) | ~ 200 GB         |
| Netflix's daily data usage            | ~ 1000 TB (1 PB) |
| YouTube (new uploads per day)         | ~ 720 TB         |
| All digitized books (Google estimate) | ~ 15 TB          |
| Entire web (text content)             | ~ 50–100 TB      |
| Internet Archive (Wayback Machine)    | > 70 PB          |

**Table 1:** Human brain vs. digital data scales (approximate).

# Key Takeaways

- ▶ The human brain likely stores  $\sim 50\text{--}60$  TB of data using synaptic strength encoding.
- ▶ That's **more than all of Wikipedia and most of the web's text content**.
- ▶ But it's still **tiny compared to the size of the entire Internet**.
- ▶ Biological information storage is efficient, flexible, and dynamic—not just about raw capacity.

# How Much Information Does the Brain Process Daily?

- ▶ **Visual input alone:**  $\sim 74$  GB/day (Koch et al., 2006)
- ▶ **Full sensory input:** Estimated at  $> 100$  GB/day
- ▶ **Total (incl. unconscious processing):** Up to  $10+$  TB/day
- ▶ Most of this information is *not* retained in long-term memory

## Takeaway

The brain filters massive streams of data, encoding only what's salient.

# What Does This Imply About Forgetting?

- ▶ If the brain stored all incoming data, it would run out of space in:
  - ▶ ~1.5 years (100 GB/day)
  - ▶ ~2 months (1 TB/day)
  - ▶ <1 week (10 TB/day)
- ▶ But that doesn't happen.

## Key Insight

**Forgetfulness isn't a flaw — it's a feature.** The brain filters, compresses, and abstracts, retaining only what serves future decisions.

# Processing vs. Storage: The Brain's Efficiency

## Information Processed Daily:

- ▶  $\sim 70\text{--}100$  GB/day (conscious perception)
- ▶ Up to **10+ TB/day** (all brain activity)

## Long-Term Storage Capacity:

- ▶  $\sim 51\text{--}57$  TB total (Samavat et al., 2024)
- ▶ Based on  $\sim 10^{14}$  synapses  $\times$  4.1–4.6 bits/synapse

## Key Insight

The brain compresses, abstracts, and forgets — storing only what matters. It's not a camera, it's a meaning-maker.

# How People Process Information

- ▶ Information is not passively received — it is actively **filtered and interpreted**.
- ▶ Two key dimensions of interpretation:
  1. **Personal filters**  
Beliefs, values, lived experience, cognitive biases
  2. **Institutional or mechanical filters**  
Media framing, educational systems, algorithmic curation

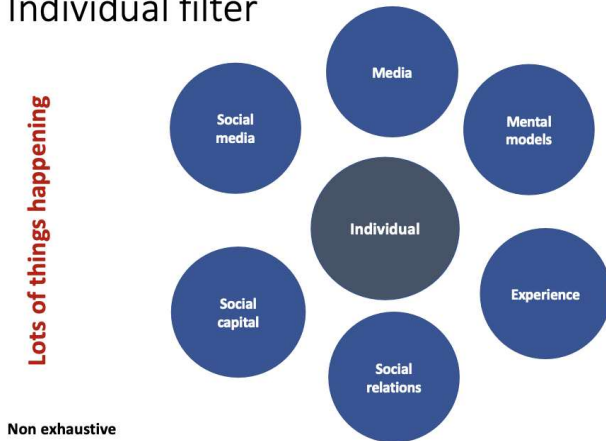
## Interpretive Divergence

Even when exposed to the same facts or evidence, individuals and groups may arrive at **radically different conclusions**.

*These filters play a crucial role in shaping narratives – especially during transitions, crises, or social change.*

# Processing information

## Individual filter



from Keynote at SHAPER Workshop 2023 on the *Political Economy of Climate (In)Action*.

# How Do We Perceive Time?

- ▶ Time perception is **psychological**, not physical
- ▶ Influenced by:
  - ▶ **Attention and arousal**
  - ▶ **Novelty and emotional intensity**
  - ▶ **Memory encoding**
- ▶ More change/events = longer perceived duration

## Example

“Time flies when you’re having fun” — but we *remember* those moments more vividly.

# Why Does the Brain Crave Experience?

- ▶ Brain = **predictive engine**
- ▶ Constantly seeks to minimize surprise
- ▶ Novel experiences provide:
  - ▶ Model updates (learning)
  - ▶ Emotional salience (dopamine, memory consolidation)
  - ▶ Subjective expansion of time

## Implication

We pursue experience not just to “feel alive” — but to update internal models of the world.

# The Experience Economy and Cognitive Design

- ▶ Routine compresses time perception
- ▶ Novelty stretches it and anchors memory
- ▶ This has real design implications:
  - ▶ Travel, art, learning, risk-taking
  - ▶ Avoid passive consumption and algorithmic dullness

## Designing for Memory

Shape experiences that maximize meaningful change, not just stimulation.

# Summary

- ▶ The brain filters and encodes vast amounts of information daily
- ▶ Our perception of time is shaped by memory, attention, and novelty
- ▶ The craving for experience is biological, not just cultural
- ▶ Designing for experience = designing for salience and memory

*“We are not made to remember days, we are made to remember moments.”*

→ the stories we tell each other to rationalize collectively what is happening are key to shaping the informational boundaries of the state.

# Stories are part of modern service sector trade

February 09 2024

## How Big Is the Media Multiplier? Evidence from Dyadic News Data

Timothy Besley, Thiemo Fetzer, Hannes Mueller

[> Author and Article Information](#)

*The Review of Economics and Statistics* 1–45.

[https://doi.org/10.1162/rest\\_a\\_01415](https://doi.org/10.1162/rest_a_01415)

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### Abstract

This paper estimates the size of the *media multiplier*, an easily generalizable model-based measure of how far media coverage magnifies the economic response to shocks. We combine monthly aggregated and anonymized credit card activity data from 114 card issuing countries in 5 destination countries with a large corpus of news coverage in issuing countries reporting on violent events in the destinations. To define and quantify the media multiplier we estimate a model in which latent beliefs, shaped by either events or news coverage, drive card activity. According to the model, media coverage can more than triple the economic impact of an event. We document, through our model, that this effect is highly heterogenous and depends on the broader media representation of countries in each others news. We speculate about the role of the media in driving international travel patterns an.

**Keywords:** [media](#), [economic behavior](#), [news shocks](#)

**Keywords:** [O1](#), [F5](#), [D8](#), [F1](#), [L8](#)

Let's begin

# ***Production Networks Now***

# Global Context

- ▶ Climate crisis, wars, and demographic transition imply a massive uncertainty shock.
- ▶ Structural transformation of the hydrocarbon-based economic system raises questions around public and private investment and the role of the state.
- ▶ Growing discussion on the boundaries of the state, firms, and individual households due to the growing role of (digital) service trade amidst a fraying global trade order.
- ▶ Escalation induces countries to focus on economic security and de-risking.

**Natural question:** Does localisation work?

BBC Home News Sport

**NEWS**

## Why firms are bringing their manufacturing back home

FINANCIAL TIMES

## Donald Trump steps up warnings to US business over offshoring

Forbes

FORBES > BUSINESS > MANUFACTURING

## Covid Is Fading, But Reshoring Isn't

News provider of the year

The Guardian UK

**Economics viewpoint**

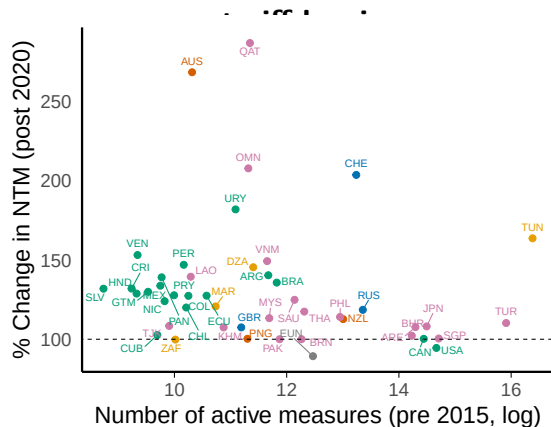
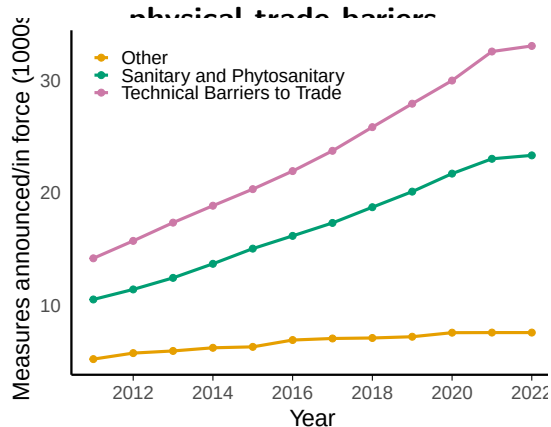
## Globalisation is not dead, but it is fading: 'glocalisation' is becoming the new mantra

The New York Times

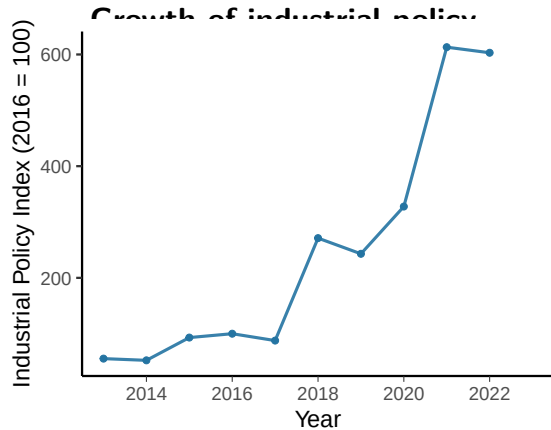
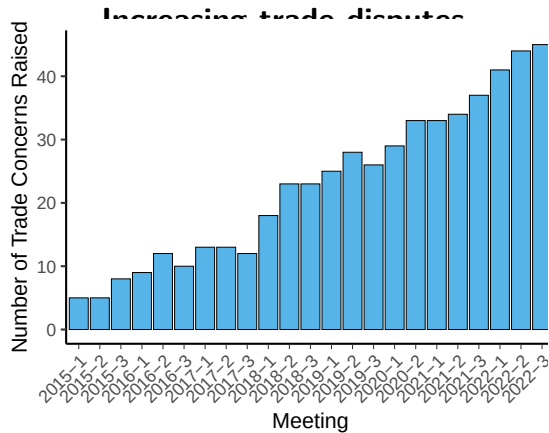
## *Supply Chain Woes Prompt a New Push to Revive U.S. Factories*

Companies are testing whether the United States can regain some of the manufacturing output it ceded in recent decades to China and other countries.

# Rising trade barriers/disputes



# Rising trade barriers/disputes



# This paper

- ▶ Build, validate and deploy a new production-network
  - ▶ Leverage novel AI/LLM tools to build a graphical dataset
  - ▶ Recovers vertical relationships across 5,000+ HS products
  - ▶ Contrast to other measurement approaches e.g. SUTs/IOTs
- ▶ Identify how trade shocks influence
  - ▶ On-shoring, aka 'reshoring', 'localization'
  - ▶ Industrial transformation
- ▶ Two empirical applications:
  - ▶ Global impact of reduced form supply-shocks
  - ▶ Difference-in-difference study of Qatar blockade

# Outline

Measurement

Validation of the Production Network

Global Patterns in Trade Data

Easy and Important Extensions

Onshoring Natural Experiment

Applications of AIPNET in a Fragmenting World

A bit of speculation

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## Measurement

Validation of the Production Network

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Easy and Important Extensions

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A bit of speculation

# Measurement Challenge

- ▶ Want to assess how **trade shocks** propagate through **production networks**
- ▶ But how to measure set of relevant **upstream goods**?
- ▶ Ideal measurement of production-linkages
  - ▶ Based on actual production processes
  - ▶ Not just market transactions
  - ▶ Highly granular to compliment rich trade data



# Introducing AIPNET

- ▶ AI-built Production Network (AIPNET)
- ▶ Leverages power of AI/LLM to systematically identify network structure
- ▶ Trained, tuned, and validated for this purpose
- ▶ Capable of 'understanding' technical requirements of over 5,000 Harmonized System (HS) product groups

# Why could AI produce a good representation of input mix?

HS **190520** Food preparations; gingerbread and the like, whether or not containing cocoa



# Why could AI produce a good representation of input mix?

HS **190520** Food preparations; **gingerbread** and the like, whether or not containing cocoa

## Gingerbread

[Article](#) [Talk](#)

From Wikipedia, the free encyclopedia

*For other uses, see [Gingerbread \(disambiguation\)](#).*

**Gingerbread** refers to a broad category of **baked goods** typically flavored with **ginger, cloves, nutmeg** and **cinnamon** and sweetened with **honey, sugar, or molasses**. Gingerbread foods vary, ranging from a moist loaf cake to forms nearly as crisp as a **ginger snap**.<sup>[1]</sup>

### Etymology [\[ edit \]](#)

Originally, the term gingerbread (from Latin *zingiber* via Old French *gingebras*) referred to preserved *ginger*. It then referred to a confection made with honey and spices. Gingerbread is often used to translate the French term *pain d'épices* (lit. 'spice bread') or the German and Polish terms *Plattkuchen* and *Piernik* respectively (lit. 'pepper cake' because it used to contain pepper) or *Lebkuchen* (of unclear etymology; either Latin *libum*, meaning "sacrifice" or "sacificial bread," or German *Laib* for loaf or German for life, *leben*). Pepper is also referenced in regional names like Norwegian *pepperkaker* or Czech *perník* (originally *peprník*).<sup>[2]</sup>

The meaning of gingerbread has evolved over time. For centuries the term referred to a traditional European *gingerbread* traditionally used to make *gingerbread men*. In the United States the first known recipe for "Soft gingerbread is:

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**Baking** is a method of preparing food that uses dry heat, typically in an **oven**, but can also be done in hot ashes, or on hot stones. The most common baked item is **bread**, but many other types of foods can be baked.<sup>[1]</sup> Heat is gradually transferred "from the surface of cakes, cookies, and pieces of bread to their center, typically conducted at elevated temperatures surpassing 300°F. Dry heat cooking imparts a distinctive richness to foods through the processes of caramelization and surface browning. As heat travels through, it transforms batters and doughs into baked goods and more with a firm, dry crust and a softer center.<sup>[2]</sup> Baking can be combined with [grilling](#) to produce a hybrid [barbecue](#) variant by using both methods simultaneously, or one after the other. Baking is related to [broasting](#) because the concept of the [masonry oven](#) is similar to that of a [smoke pit](#).



Freshly baked bread

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Freshly baked bread

## Oven

Article Talk

Read View source

From Wikipedia, the free encyclopedia

For clay ovens, see [Primitive clay oven](#). For other uses, see [Ovens \(disambiguation\)](#).

Not to be confused with [Industrial furnace](#).

An **oven** is a *tool* which is used to expose materials to a hot environment. Ovens contain a hollow chamber and provide a means of heating the chamber in a controlled way.<sup>[1]</sup> In use since *antiquity*, they have been used to accomplish a wide variety of tasks requiring controlled heating.<sup>[2]</sup> Because they are used for a variety of purposes, there are many different types of ovens. These types differ depending on their intended purpose and based upon how they generate heat.

Ovens are often used for *cooking*, where they can be used to heat food to a desired temperature. Ovens are also used in the manufacturing of *ceramics* and *pottery*; these ovens are sometimes referred to as *kilns*. Metallurgical *furnaces* are ovens used in the manufacturing of *metals*, while *glass furnaces* are ovens used to produce *glass*.

There are many methods by which different types of ovens produce heat. Some ovens heat materials using the *combustion* of a fuel, such as *wood*, *coal*, or *natural gas*,<sup>[3]</sup> while many employ *electricity*. Microwave ovens heat materials by exposing them to *microwave radiation* while electric ovens and electric *furnaces* heat materials using *resistive heating*. Some ovens use forced *convection*, the movement of *gases* inside the heating chamber, to enhance the heating process, or, in some cases, to change the properties of the material being heated, such as in the *tempering*

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Industrial oven

Article Talk

From Wikipedia, the free encyclopedia

This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.  
*Find sources: "Industrial oven" – news · newspapers · books · scholar · JSTOR (February 2022)* [Learn how and when to remove this message](#)

**Industrial ovens** are heated chambers used for a variety of industrial applications, including [curing](#), [cooking](#), or [heating](#) components, parts or final products. Industrial ovens can be used for large or small volume applications, in batch or continuously with a conveyor line, and a variety of temperature ranges, sizes and configurations.

Such ovens are used in many different applications, including chemical processing, food production, and ovens in the electronics industry, where circuit boards are run through a conveyor belt to attach surface mount components.<sup>[1]</sup>

Common types of industrial ovens include:

- **Curing ovens** – Designed to cause a chemical reaction in a substance once a specific temperature is reached. *Powder coating* is one common curing oven use.
- **Drying ovens** – Designed to remove moisture. Typical applications are pre-treating and painting. Such ovens are also sometimes known as *kilns*, though they do not reach the same high temperatures as are used in *ceramic kilns*.

**Baking ovens** – Combines the function of curing and drying ovens.

- **Reflow Ovens** – A reflow oven is a machine used primarily for reflow coating of surface mount electronic components to printed circuit boards (PCBs). The oven contains multiple zones, which can be individually controlled for temperature. Generally, there are several heating zones followed by one or more cooling zones. The PCB moves through the oven on a [conveyor belt](#), and is therefore subjected to a controlled time-temperature profile.

- **Batch ovens** – Also called cabinet or *Wibbel*/*Wibbel*-in ovens, batch ovens allow for curing, drying or baking in small batches using wheeled racks, carts or trucks. Ovens such as this are often found in large volume bakeries in places such as supermarkets.

- **Conveyor or Continuous Ovens** – Typically part of an automated conveyor processing line, conveyor ovens



Industrial convection oven used in the manufacturing of small components. Heating by gas-fired heat exchanger; fully automated control system; built on temperature within 2°C.



Automated conveyor ovens used in the manufacturing of small components.

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ChatGPT 4o ▾



 How is full fat milk produced?



ChatGPT can make mistakes. Check important info.

## How is full fat milk produced?



Full-fat milk, also known as whole milk, is produced through a series of processes that maintain its natural fat content, typically around 3.25% in most countries. Here's a breakdown of the process:

### 1. Milking the Cow:

- The milk production process begins with cows being milked, either manually or using machines. Modern dairies use automated milking machines to ensure hygiene and efficiency.

### 2. Filtration and Cooling:

- After the cow is milked, the raw milk is immediately filtered to remove any impurities (such as dirt or hair) that may have been introduced during the milking process.
- The milk is then rapidly cooled to about 4°C (39°F) to prevent bacterial growth before being transported to a processing plant.

### 3. Separation:

- At the dairy plant, the raw milk undergoes a separation process where the cream is separated from the skim milk using a centrifuge. This allows the dairy to control the fat content in the final product.
- For full-fat or whole milk, a portion of the cream is added back to achieve the desired fat percentage, typically around 3.25%.

### 4. Pasteurization:

- Pasteurization involves heating the milk to a specific temperature (around 72°C or 161°F) for about 15–20 seconds and then cooling it quickly. This process kills harmful bacteria while preserving nutrients.

### 5. Homogenization:

- In homogenization, the milk is forced through small holes at high pressure, breaking down the fat molecules so they remain evenly distributed throughout the milk. This prevents the cream



ChatGPT 4o ▾



 List the capital goods I need|



ChatGPT can make mistakes. Check important info.

### How is full fat milk produced?

Full-fat milk, also known as whole milk, is produced through a series of processes that maintain its natural fat content, typically around 3.25% in most countries. Here's a breakdown of the process:

#### 1. Milking the Cow:

- The milk production process begins with cows being milked, either manually or using machines. Modern dairies use automated milking machines to ensure hygiene and efficiency.

#### 2. Filtration and Cooling:

- After the cow is milked, the raw milk is immediately filtered to remove any impurities (such as dirt or hair) that may have been introduced during the milking process.
- The milk is then rapidly cooled to about 4°C (39°F) to prevent bacterial growth before being transported to a processing plant.

#### 3. Separation:

- At the dairy plant, the raw milk undergoes a separation process where the cream is separated from the skim milk using a centrifuge. This allows the dairy to control the fat content in the final product.
- For full-fat or whole milk, a portion of the cream is added back to achieve the desired fat percentage, typically around 3.25%.

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- In homogenization, the milk is forced through small holes at high pressure, breaking down the fat molecules so they remain evenly distributed throughout the milk. This prevents the cream

### List the capital goods I need?

To produce full-fat milk on a dairy farm, you'll need several **capital goods** (long-term assets used in the production process). Here is a list of typical capital goods necessary for dairy farming:

#### 1. Dairy Cows:

- High-quality dairy cows (such as Holstein, Jersey) are one of the most significant investments for milk production.

#### 2. Milking Equipment:

- Milking Machines:** Automated or semi-automated systems for milking cows efficiently.
- Milking Parlors:** Specialized facilities designed for the milking process, including cow stalls and milking lines.

#### 3. Cooling and Storage Equipment:

- Bulk Cooling Tanks:** Large stainless steel tanks that cool and store raw milk before it's transported to processing facilities.
- Milk Silos:** Large storage tanks for bulk milk before transportation or processing.

#### 4. Processing Equipment:

- Pasteurizers:** Equipment used to heat milk to a specific temperature to kill bacteria.
- Homogenizers:** Equipment that breaks down fat molecules to ensure even distribution in milk.
- Cream Separators:** Machines that separate the cream from the milk, useful for standardizing fat content.

#### 5. Feed Production and Storage:

- Tractors and Feed Mixers:** Essential for producing and delivering feed to the cows.

ChatGPT 4o

List the capital goods I need

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

List all the raw material inputs

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

List all the raw material inputs

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

What machinery and plant equipment is used

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

Explain the technical equipment

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

What are the most critical inputs?

ChatGPT can make mistakes. Check important info.

ChatGPT 4o

List any other technical requirements

ChatGPT can make mistakes. Check important info.

## (Top)

[Etymology and terminology](#)> [Types of consumption](#)> [History](#)> [Sources](#)> [Production worldwide](#)> [Composition](#)> [Processing](#)[Pasteurization](#)[Filtration](#)[Creaming and homogenization](#)[UHT](#)> [Nutrition and health](#)[Evolution of lactation](#)> [Bovine growth hormone supplementation](#)> [Varieties and brands](#)[Use in other food products](#)[In language and culture](#)[Non-culinary uses](#)[Interspecies milk consumption](#)[See also](#)[References](#)[Further reading](#)

# Milk

From Wikipedia, the free encyclopedia



*This article is about the fluid produced by the mammary glands of mammals. For the milk-like beverages derived from plants, see [Plant milk](#). For other uses of the word, see [Milk \(disambiguation\)](#).*

**Milk** is a white liquid [food](#) produced by the [mammary glands](#) of [mammals](#). It is the primary source of [nutrition](#) for young mammals (including [breastfed](#) human infants) before they are able to [digest](#) solid food.<sup>[1]</sup> Milk contains many nutrients, including [calcium](#) and [protein](#), as well as [lactose](#) and [saturated fat](#).<sup>[2]</sup> Immune factors and immune-modulating components in milk contribute to [milk immunity](#). Early-[lactation](#) milk, which is called [colostrum](#), contains [antibodies](#) and immune-modulating components that [strengthen](#) the [immune system](#) against many diseases. The US [CDC agency](#) recommends that children over the age of 12 months should have two servings of dairy milk products a day,<sup>[3]</sup> and more than six billion people worldwide consume milk and milk products.<sup>[4]</sup>

As an agricultural product, [dairy](#) milk is [collected from farm animals](#), mostly [cattle](#). In 2011, [dairy farms](#) produced around 730 million [tonnes](#) (800 million short tons) of milk<sup>[5]</sup> from 260 million dairy cows.<sup>[6]</sup> [India](#) is the world's largest producer of milk and the leading exporter of [skimmed milk powder](#).<sup>[7][8]</sup> New Zealand, Germany, and the Netherlands are the largest exporters of milk products.<sup>[9]</sup> Between 750 and 900 million people live in dairy-farming households.<sup>[4]</sup>

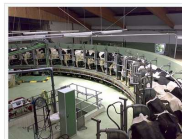
## Etymology and terminology

The term *milk* comes from "Old English *meoluc* (West Saxon), *milc* (Anglian), from Proto-Germanic *\*meluks* "milk" (source also of Old Norse *mjolk*, Old Frisian *melok*, Old Saxon *miluk*, Dutch *melk*, Old High German *miluh*, German *Milch*, Gothic *miluks*)".<sup>[10]</sup>

Since 1961, the term *milk* has been defined under [Codex Alimentarius](#) standards as "the normal mammary secretion of milking animals obtained from one or more milkings without either addition to it or extraction from it, intended for consumption as liquid milk or for further processing."<sup>[11]</sup> The term *dairy* refers to animal milk and animal milk production.



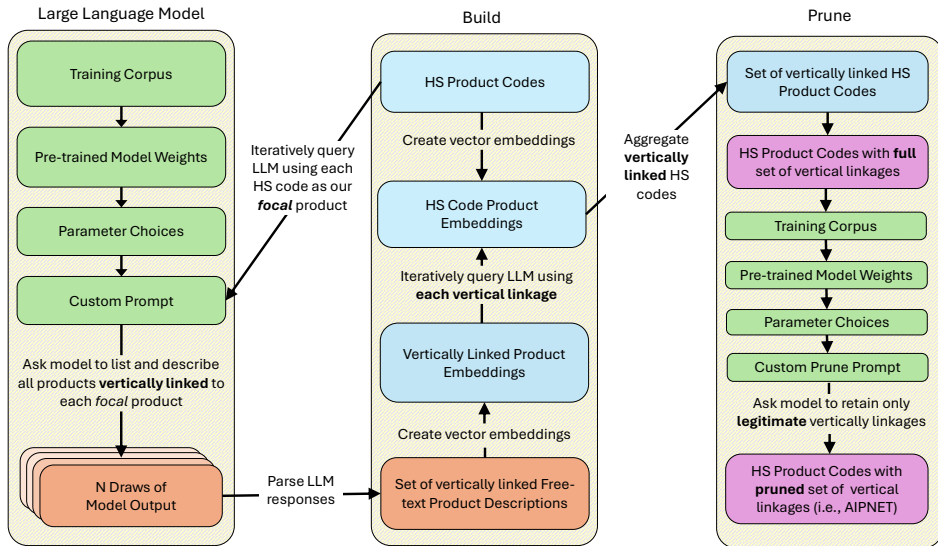
A glass of cow milk



Cows in a rotary milking parlor



# AI pipeline to build AIPNET



# Let me walk you through the approach step by step

1. Forward prompt
2. Backward prompt
3. Dyadic plausibility false-positive filter prompt

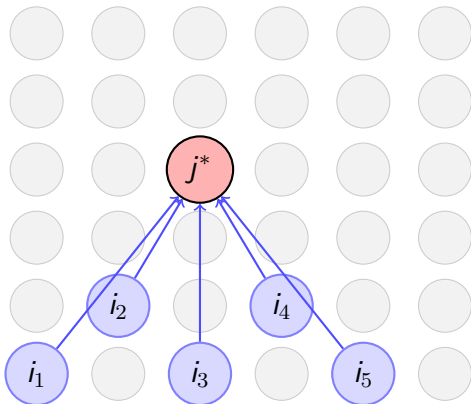
# Forward Prompt: Retrieving Inputs for a given Output

## Prompt Strategy: Forward

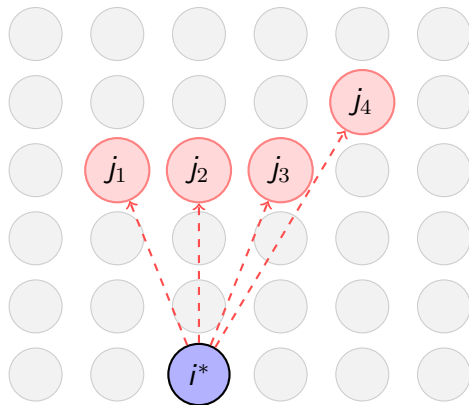
*To produce output  $j^*$ , what inputs  $i$  are needed?*

### Approach:

- ▶ Start from a known output  $j^*$
- ▶ Retrieve likely inputs  $i$
- ▶ Result: Broad set of candidate input links



# Backward Prompt: Inferring Outputs from a give Input



## Prompt Strategy: Backward

*Given input  $i^*$ , what outputs  $j$  could it help produce?*

## Approach:

- ▶ Begin with input  $i^*$
- ▶ Infer all possible outputs
- ▶ Result: Another candidate set of links

# Example Prompts and Output

## Prompt examples

| Section                              | Prompt A: Measuring Outputs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Prompt B: Measuring Inputs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| System Guidance                      | You are an assistant with expertise in supply chains and production processes. When given a product description, identify all products (narrowly defined physical products) which this <b>[focal product]</b> is used to produce i.e. list output goods for which this focal product is the input). Prioritize outputs for which the focal input good is an essential input. Consider both <b>[capital]</b> , <b>[intermediary]</b> , and <b>[final outputs]</b> . When responding, you will follow the JSON schema provided in the response format. For the subfield 'product description', you should use similar language to the detailed Harmonized System (HS) of traded goods products. Some examples of these product descriptions include: | You are an assistant with expertise in supply chains and production processes. When given a product description, identify all products (narrowly defined physical products) which this <b>[focal product]</b> requires as an input i.e. list input goods which are used to produce this focal product). Prioritize inputs which are essential to producing the focal good. Consider both <b>[raw materials]</b> , <b>[intermediary]</b> , and <b>[capital]</b> inputs. When responding, you will follow the JSON schema provided in the response format. For the subfield 'product description', you should use similar language to the detailed Harmonized System (HS) of traded goods products. Some examples of these product descriptions include: |
| Examples Drawn from HS Product Codes | <ul style="list-style-type: none"><li>• Portland cement, aluminous cement (ciment fondu), slag cement, supersulphate cement and similar hydraulic cements, whether or not coloured or in the form of clinkers</li><li>• Fruit, edible; apples, fresh</li><li>• Engines; pneumatic power engines and motors, other than linear acting (cylinders)</li><li>• Milking machines and dairy machinery ...</li></ul>                                                                                                                                                                                                                                                                                                                                      | <ul style="list-style-type: none"><li>• Portland cement, aluminous cement (ciment fondu), slag cement, supersulphate cement and similar hydraulic cements, whether or not coloured or in the form of clinkers</li><li>• Fruit, edible; apples, fresh</li><li>• Engines; pneumatic power engines and motors, other than linear acting (cylinders)</li><li>• Milking machines and dairy machinery ...</li></ul>                                                                                                                                                                                                                                                                                                                                          |
| Structuring Output                   | Only include products that are physical in nature and traded internationally between countries. List up to 20 output products, focusing on the goods which <b>[require the direct contribution of the focal input product]</b> . You will list your 20 responses in a JSON format provided in the response format. This format includes a description of the <b>[output product]</b> , an importance score (between 1 and 10), and a classification of the <b>[output product]</b> as either 'intermediary' or 'capital'.                                                                                                                                                                                                                          | Only include products that are physical in nature and traded internationally between countries. List up to 20 input products, focusing on the goods which are <b>[directly required to produce the focal product]</b> . You will list your 20 responses in a JSON format provided in the response format. This format includes a description of the <b>[input product]</b> , an importance score (between 1 and 10), and a classification of the <b>[input product]</b> as either 'raw material', 'intermediary', or 'capital'.                                                                                                                                                                                                                        |
| Focal Product                        | <b>[PRODUCT DESCRIPTIONS]</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>[PRODUCT DESCRIPTIONS]</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## Focal finished good: Footwear, With Outer Soles Of Rubber,...

```
{
  "index": 0,
  "message": {
    "role": "assistant",
    "content": {
      "products": [
        {
          "product_description": "Rubber; synthetic, in primary forms or in plates, sheets or strip",
          "importance_score": 8,
          "classification": "intermediary"
        },
        {
          "product_description": "Leather; of bovine or equine animals, without hair on, tanned or crust, further prepared after tanning or crusting, including parchment-dressed leather",
          "importance_score": 10,
          "classification": "intermediary"
        },
        {
          "product_description": "Textile fabrics; coated with gum or amylaceous substances, of a kind used for the outer soles of footwear",
          "importance_score": 7,
          "classification": "intermediary"
        },
        {
          "product_description": "Plastic; in primary forms",
          "importance_score": 6,
          "classification": "intermediary"
        },
        {
          "product_description": "Thread; of cotton, not put up for retail sale",
          "importance_score": 5,
          "classification": "intermediary"
        },
        {
          "product_description": "Adhesives; based on rubber or plastics (including artificial resins)",
          "importance_score": 7,
          "classification": "intermediary"
        },
        {
          "product_description": "Machines; for making or repairing footwear",
          "importance_score": 9,
          "classification": "capital"
        },
        {
          "product_description": "Insoles; removable, of any material",
          "importance_score": 5,
          "classification": "intermediary"
        }
      ]
    }
  }
}
```

## Use Embeddings to Map In Nomenclatures

Attach any nomenclature version to the description of the products using embeddings. An embedding is a mapping:

$$f : \mathcal{X} \rightarrow \mathbb{R}^d$$

where  $\mathcal{X}$  is a set of objects (e.g., documents or words). For example with `mxbai-embed-large`,  $|d| = 1024$ . Let  $n_{hs}$  indicate the dimensionality of the nomenclature.

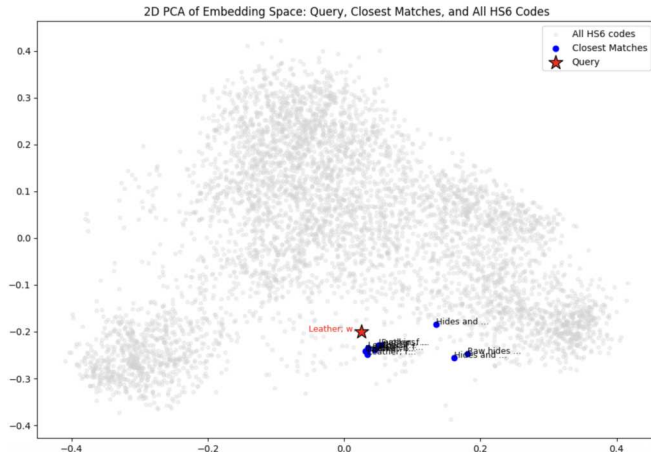
We calculate

- ▶ We embed the target nomenclature, e.g. at HS6 level  $f(x) = \mathbb{R}^{n_{hs} \times d}$
- ▶ We embed the document that we want to map to a nomenclature  $f(y) = \mathbb{R}^{1 \times d}$

Compute pairwise dissimilarity

$$\text{sim}(x, y) = \frac{f(x) \cdot f(y)}{\|f(x)\| \|f(y)\|} \in \mathbb{R}^{1 \times n_{hs}}$$

## Side step: Use Embeddings to Map In Nomenclatures



→ illustration of 1024 dimensional embedding vector space mapped into 2 dimensional vector space

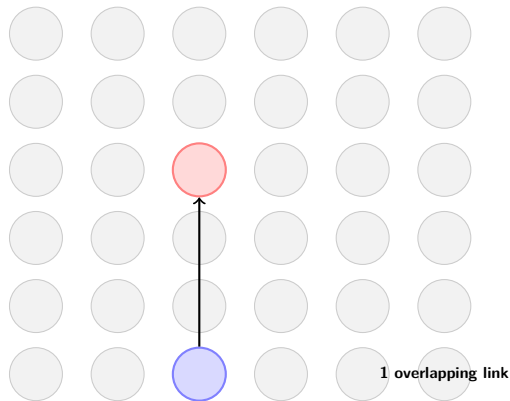
# False Positive Pruning AI Match Validation of Confirmed Links

## Intersection + Validation

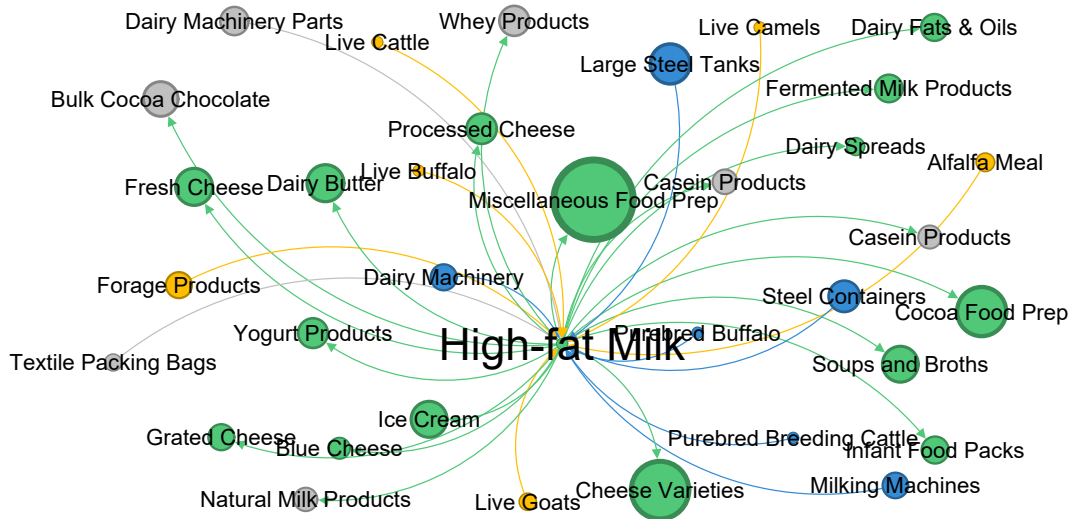
*Is this detected link plausible?*

### Approach:

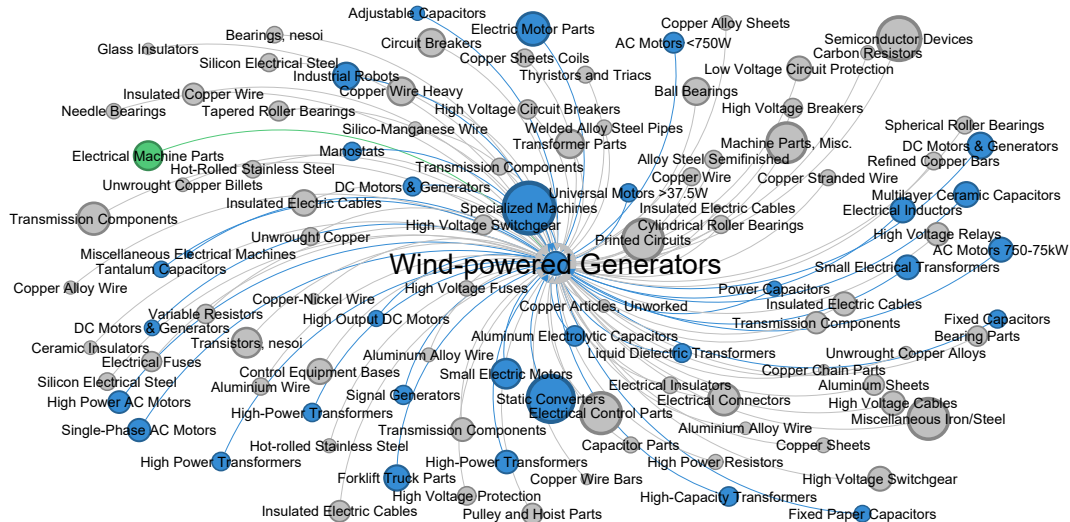
- ▶ Compare forward and backward sets
- ▶ Keep only overlaps
- ▶ Result: 1 confirmed link shown



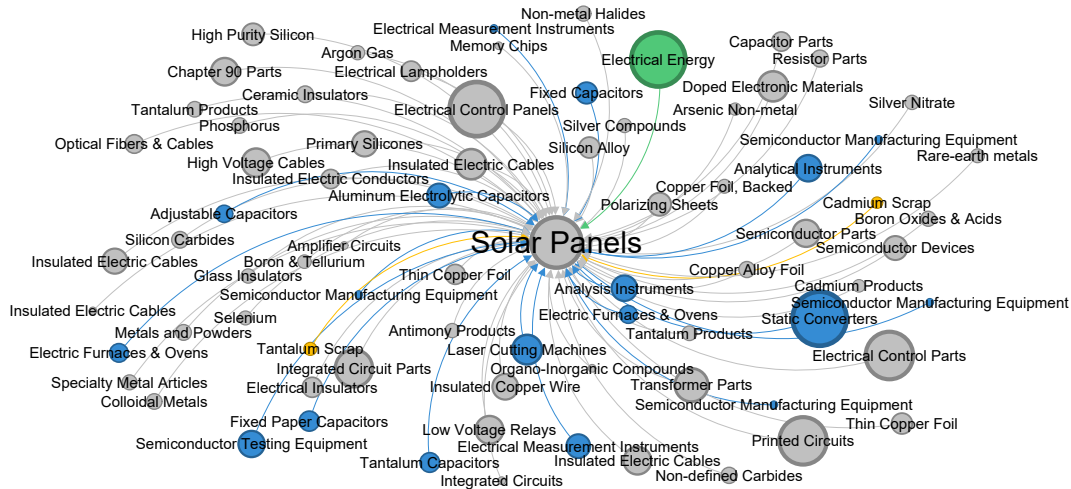
Example output: High-fat Milk



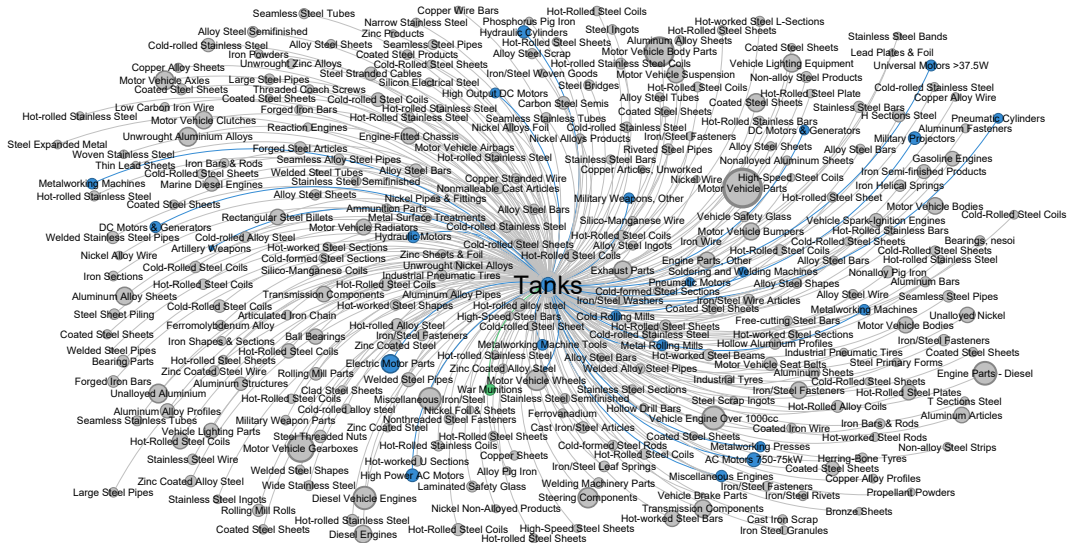
## Example output: Wind-powered Generators



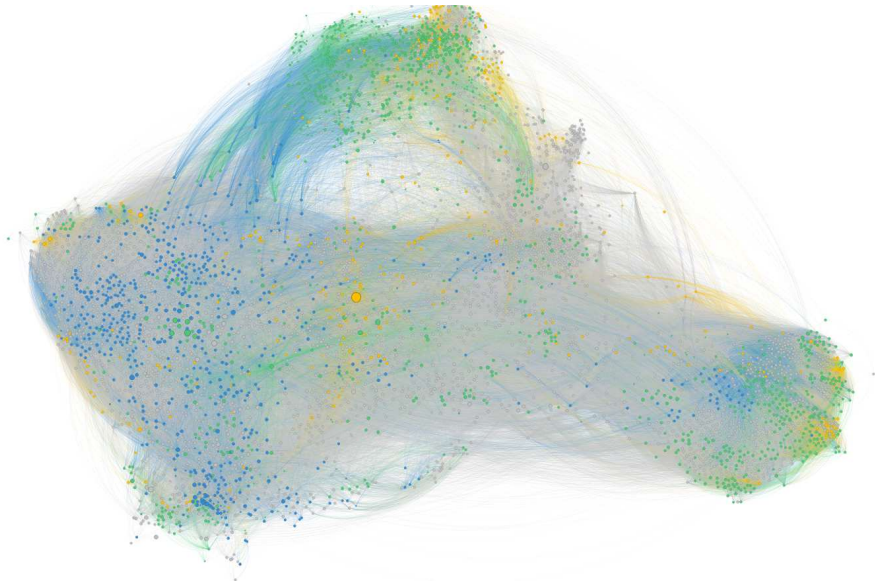
## Example output: Solar Panels



## Example output: Tanks



# AI-built Production Network (AIPNET)



## Network Properties of AIPNET (HS6 Level)

| Property                       | HS6     | HS4    |
|--------------------------------|---------|--------|
| Number of Nodes                | 5,633   | 1,190  |
| Number of Edges                | 980,018 | 48,212 |
| Average Degree                 | 347.96  | 81.03  |
| Network Density                | 0.03    | 0.03   |
| Global Clustering Coefficient  | 0.37    | 0.32   |
| Assortativity                  | 0.14    | 0.06   |
| Number of Connected Components | 1       | 1      |
| Size of Largest Component      | 5,633   | 1,190  |

# Outline

Measurement

Validation of the Production Network

Global Patterns in Trade Data

Easy and Important Extensions

Onshoring Natural Experiment

Applications of AIPNET in a Fragmenting World

A bit of speculation

# Validation

- ▶ Compare AIPNET to Human Labelling
  - ▶ Explore quality of links versus human labels
- ▶ Alternative AI models for binary labelling
  - ▶ Explore other AI models for quality
- ▶ Compare AIPNET to Input-Output Tables (IOTs)
  - ▶ Recast Product-level network into IOT structure
  - ▶ Compare Input-use intensity to AIPNET product linkages
- ▶ Compare to product-level supply chain position measures:
  - ▶ 'Upstreamness' (Fally, 2016; Antras et al. 2018)
  - ▶ Product Complexity Index (PCI) (Hausman & Hidalgo, 2014)
- ▶ Conduct perturbation/placebo tests
  - ▶ Uses Erdos-Renyi network perturbations
  - ▶ Evaluate validation exercises of more 'random' networks

# LLM-Architecture Predicts Human Labels Well

- ▶ 3 PhD students evaluated 3,000 (random) edges (50% true edges)
- ▶ The students reported difficulty in performing the task
- ▶ Auditor labels represent a general validation rather than definitive ground truth.

Confusion Matrix

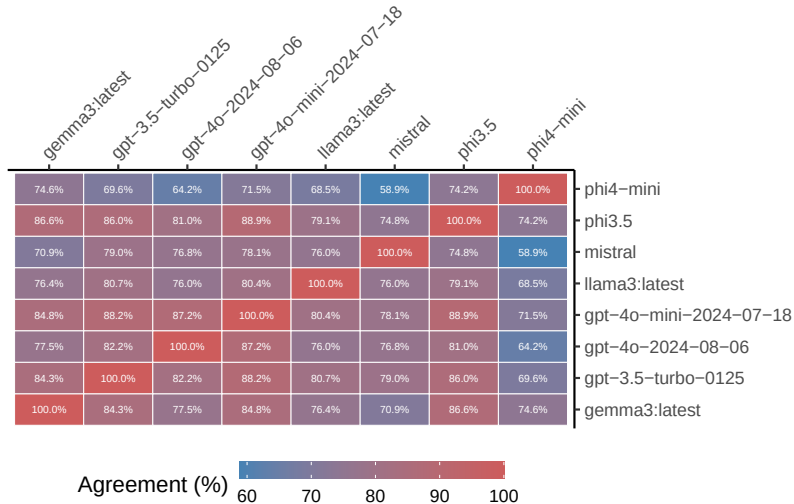
| Auditor | AIPNET |       |
|---------|--------|-------|
|         | True   | False |
| True    | 44.8   | 5.3   |
| False   | 1.0    | 48.8  |

Performance Metrics

| Metric     | Value |
|------------|-------|
| Precision  | 0.98  |
| Recall     | 0.89  |
| Accuracy   | 0.94  |
| Error Rate | 0.06  |
| F1 Score   | 0.93  |

**Note:** Precision =  $\frac{TP}{TP+FP}$ ; Recall =  $\frac{TP}{TP+FN}$ ;  
Accuracy =  $\frac{TP+TN}{Total}$ ; Error Rate =  $\frac{FP+FN}{Total}$ ; F1  
Score =  $2 \cdot \frac{Precision \cdot Recall}{Precision+Recall}$

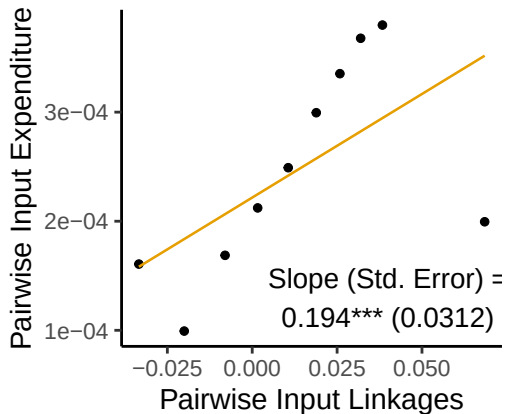
# Validation Across Different LLMs



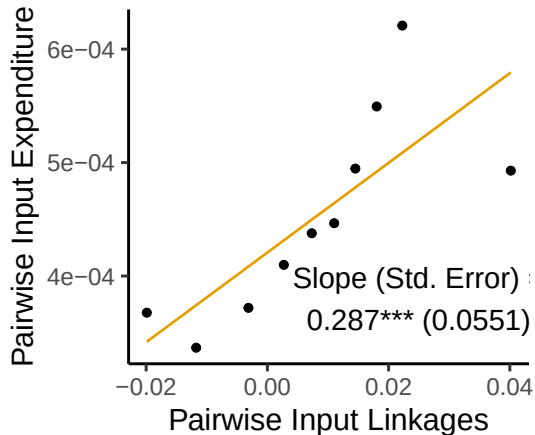
→ use quantized local LLMs which are inferior to large scale unquantized LLMs

# AIPNET strongly correlates with Input-Output Tables

US

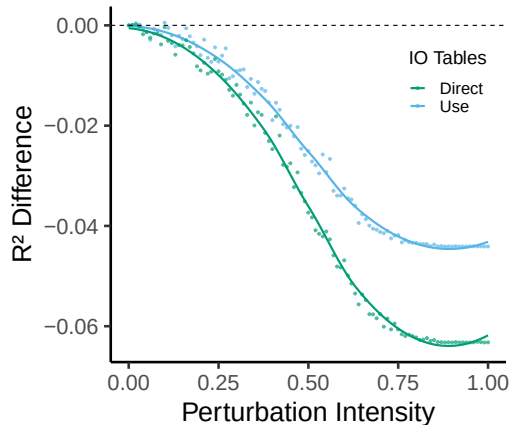


Mexico

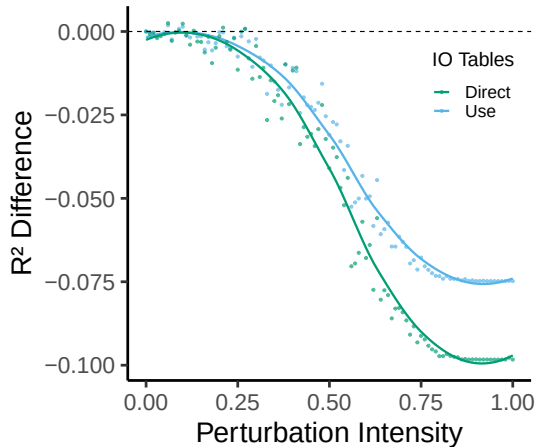


# Perturbing network attenuated validation estimates

**US**



**Mexico**



# Final Thoughts on Measurement

- ▶ AIPNET is not perfect...
  - ▶ Discrete edges, but can address econometrically
  - ▶ Assumes globally homogeneous technical processes
- ▶ But it has several notable strengths:
  - ▶ Highly granular
  - ▶ Can be used directly with trade data
  - ▶ Accurately recovers technical requirements
  - ▶ Standardized nomenclature
  - ▶ Uncensored by market configuration / vertical integration
  - ▶ Strongly correlated with existing network representations

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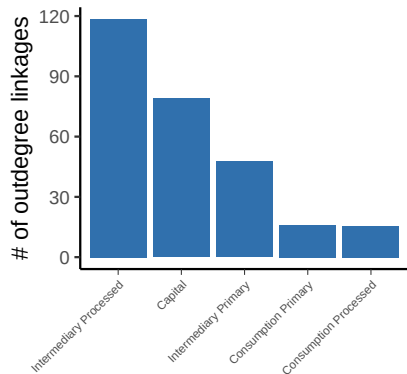
Onshoring Natural Experiment

Applications of AIPNET in a Fragmenting World

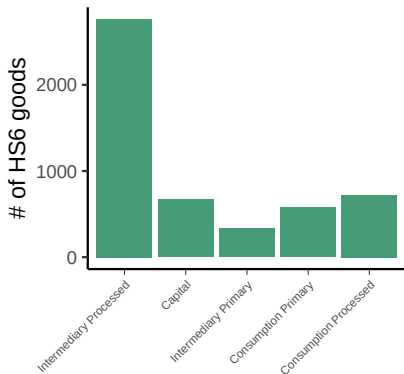
A bit of speculation

# Relationship Between BEC Classification and Number of Output Uses for HS6 Goods

**Output links by end-use type**



**# of HS6 goods by end-use type**



# Integrating AIPNET with Topology of Global Trade Data

We develop a new measure of criticality or importance of an input that integrates trade data with AIPNET

- ▶  $\mathbf{A}$  provides the AIPNET adjacency matrix
- ▶  $TC_i$  trade concentration captures how much of the trade in a product is dominated by a few players or countries
- ▶  $GTS_i$  how much of the overall trade a product represents.

# Integrated Global Product Centrality (IGPC)

**IGPC:** Measures product importance in trade, extending PageRank algorithm.

$$\mathbf{X} = (1 - d)\mathbf{B} + d\mathbf{A}\mathbf{W}\mathbf{X}$$

$\mathbf{X}$ : IGPC scores,  $d$ : damping factor,  $\mathbf{B}$ : base importance,  $\mathbf{A}$ : adjacency matrix (AIPNET),  $\mathbf{W}$ : weight matrix

Base importance:

$$B_i = TC_i^\alpha \times GTS_i^\beta$$

Weight matrix:

$$W_{ij} = GTS_i^\gamma$$

where  $TC$ : Trade Concentration,  $GTS$ : Global Trade Share, and  $\alpha, \beta, \gamma$ : weighting parameters.

# Integrated Global Product Centrality (IGPC)

IGPC update equation for a single product  $i$  can be expressed as:

$$X_i^{(t+1)} = (1 - d)B_i + d \sum_{j \in N_{out}(i)} \frac{W_{jj}X_j^{(t)}}{\sum_{k \in N_{in}(j)} W_{kk}} \quad (1)$$

where  $N_{out}(i)$  is the set of products using  $i$  as an input,  $N_{in}(j)$  is the set of products used as inputs for  $j$ .  $B_i$  is the base importance of product  $i$ :

$$B_i = \left( \frac{TC_i - \min(TC)}{\max(TC) - \min(TC)} \right)^\alpha \times \left( \frac{GTS_i - \min(GTS)}{\max(GTS) - \min(GTS)} \right)^\beta \quad (2)$$

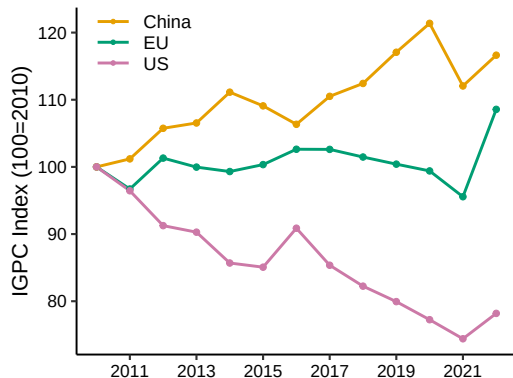
where  $TC_i$  is the Trade Concentration and  $GTS_i$  is the Global Trade Share of product  $i$ . The diagonal element  $W_{ii}$  in  $\mathbf{W}$  corresponding to product  $i$  is given by

$$W_{ii} = \left( \frac{GTS_i - \min(GTS)}{\max(GTS) - \min(GTS)} \right)^\gamma \quad (3)$$

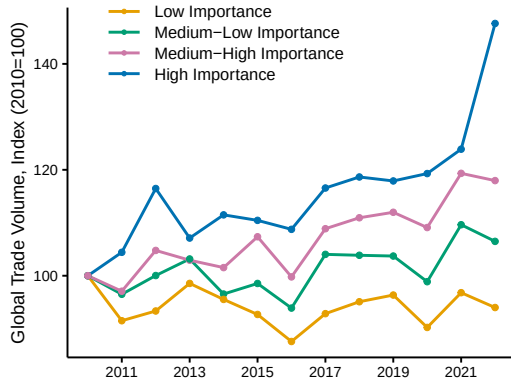
showing how the IGPC score of a product depends on its position in the AIPNET structure, specifically its relationship to downstream products.

# Diverging trends in IGPC weighted imports across countries and product centrality levels

## Within country trends (raw data)

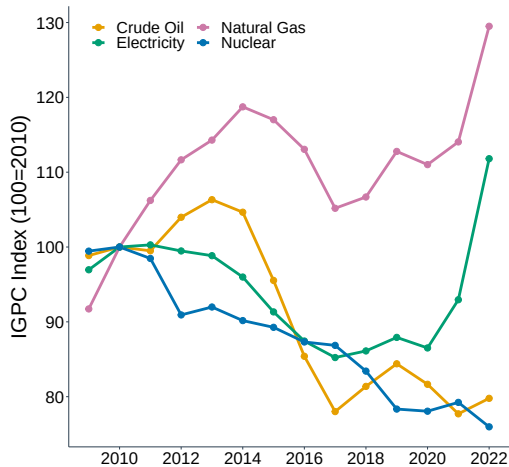


## Between product trends (raw data)

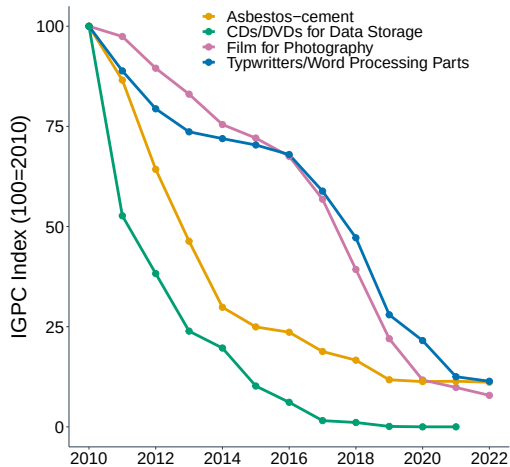


# Changes in Product Importance in Global Supply Chains

## Energy Products

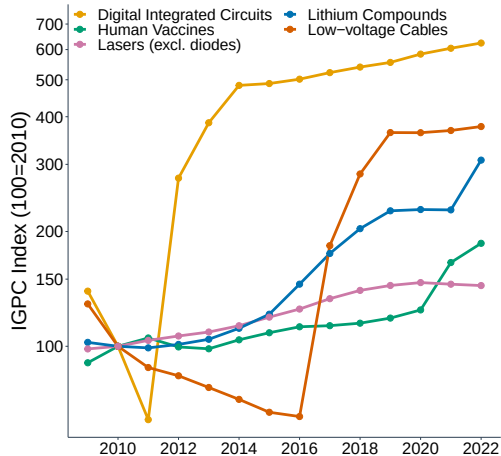


## Declining Products

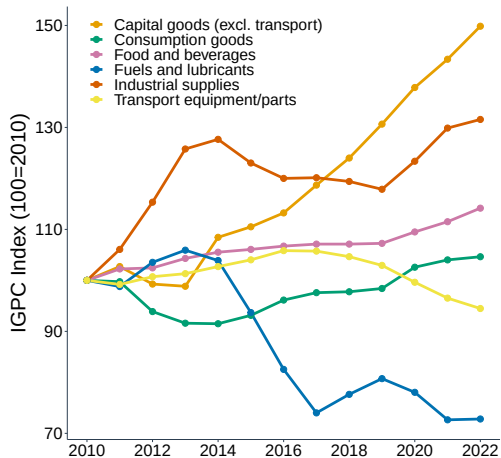


# Changes in Product Importance in Global Supply Chains

## Emerging Products



## Broad Economics Categories



# Outline

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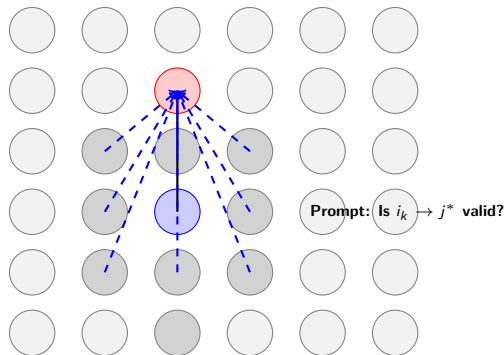
A bit of speculation

# Looking for support to extend this work

We are interested in extending this work in three particular dimensions:

- ▶ Incorporate **elasticities of substitution** between different inputs  
*think*: establish which inputs could be substituted
- ▶ Capture **topological sorting** of a value chain around a product  
*think*: endogeneity of industrial organisation and specialisation to topology of production process
- ▶ Introduce **local varieties** of the production network that incorporates context  
*think*: what local environmental factors may affect the production process.
- ▶ Incorporate a **labor market module** to capture potential  $K$ ,  $L$  substitution  
*think*: description of production process can be mapped to tasks which can be mapped to occupations

# Learning product or input substitutability



## Prompting Intuition

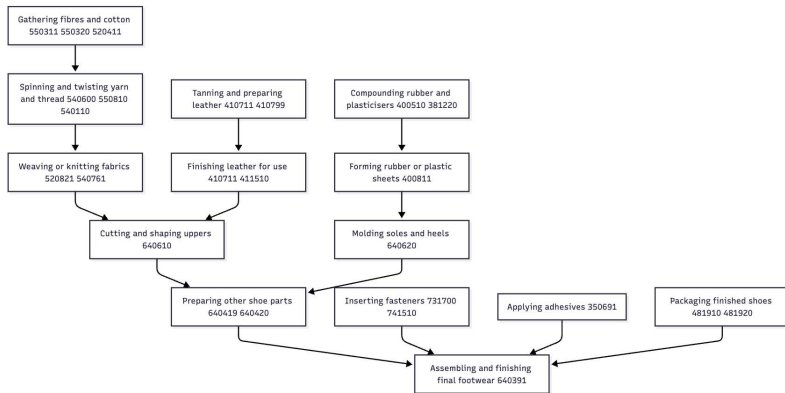
Given a confirmed link  $i^* \rightarrow j^*$ , we ask:  
*"Can other nearby inputs  $i_k$  also be used to produce  $j^*$ ?"*

## Steps:

- ▶ Define a local substitution zone ( $3 \times 3$  around  $i^*$ )
- ▶ Prompt the model for each  $i_k$ : "Is  $i_k \rightarrow j^*$  valid?"
- ▶ Evaluate substitutability (e.g. function, classification, taxonomic similarity)

Constraints like substitutability within same HS4 category or physical incompatibility to block substitutions.

# Topological sorting to understand process



→ this bundles products into close substitutes for long lists of varieties of inputs (e.g. various yarns)

# AI-Generated Production Networks: Global Trade Pattern and Evidence of Production Network Spillovers

**Thiemo Fetzner**  
Warwick, Bonn, CEPR

Peter John Lambert  
LSE, POID

Bennet Feld  
LSE

Prashant Garg  
Imperial College, IFC

October 27, 2026

## In this part study global spillovers

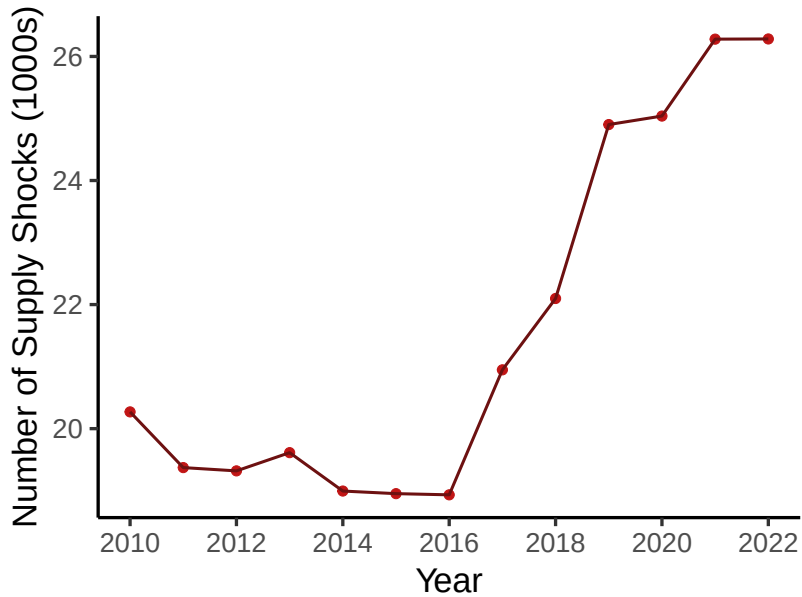
Proceed with providing a collage of evidence on role of supply shocks.

- ▶ Characterize supply shocks revealed by global trade data
- ▶ Explore trends in global trade
- ▶ Present a cross-country exercise linking downstream price shocks and onshoring
- ▶ Discuss a natural experiment of a country subject to an economic blockade

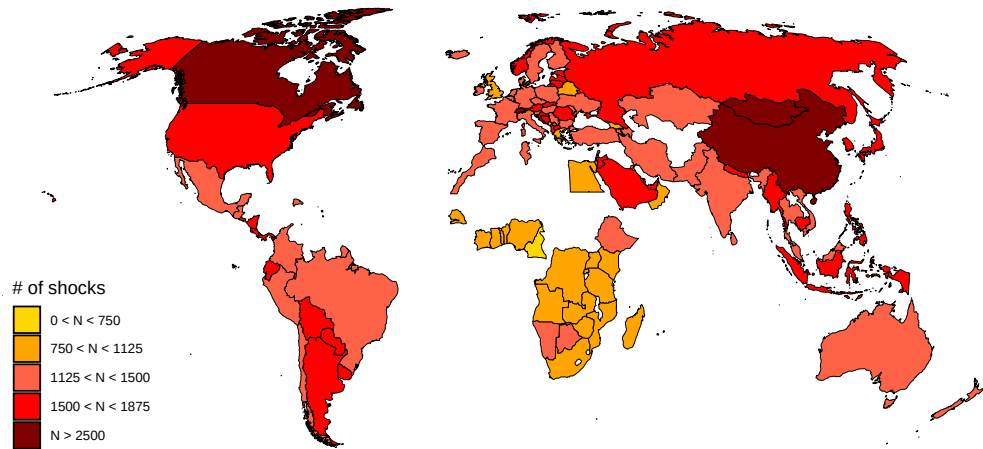
# Data

- ▶ Harmonised System (HS) Codes
  - ▶ 5,648 product codes from 2012 edition
  - ▶ Six-digit numerical codes, hierarchical structure
- ▶ International Trade Flows
  - ▶ BACI International Trade Database
  - ▶ 200 countries, 5,000 products at 6-digit HS level
- ▶ Qatar Customs Data
  - ▶ Monthly imports/exports (Jan 2012 - Jun 2023)
  - ▶ 8-digit HS categories

## Persistent Price Shocks

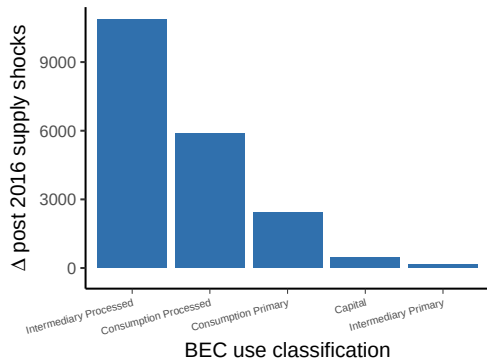


# Geographic distribution of price shocks

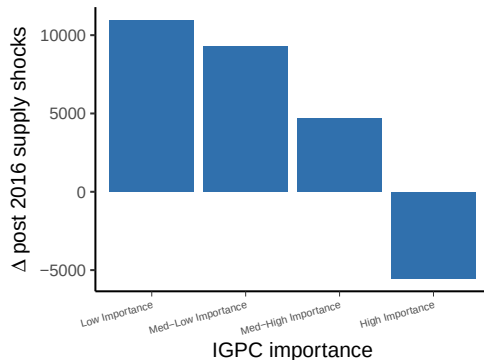


# Characterisation of the Supply Shock

## By BEC End-Use

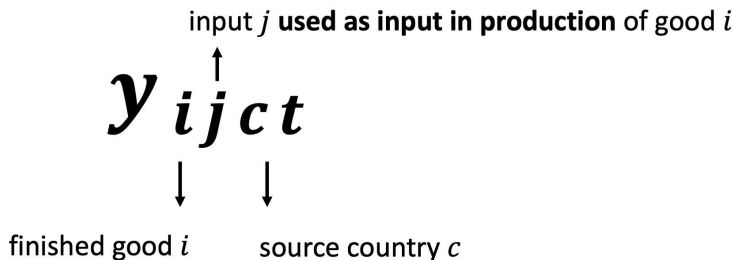


## By IGPC



# Ideal trade data to study onshoring

Ideal trade dataset would have us observe **purpose or activity specific import data** – that is for **every good  $i$**  we observe imports that are **linked to the production** of that good  $j$  from **country  $c$**  in **year  $t$** .



→ implies supply chain transparency

## Actual data typically available

Rather than knowing the specific *use* of an import as part of a value chain

$$y_{ijct}$$

Yet, we only observe **total imports not linked to it's specific or intended use.**  
That is we observe:

$$y_{ict}$$

$$y_{jct}$$

where good  $i$  and good  $j$  may or may not be linked in an input/output relationship.

Nevertheless, we have **strong reasons to believe** that some imports of good  $j$  may **occur as part of an input in the production of good  $i$ .**

## Actual data typically available

Estimate a fully dyadic specification

$$\log(\text{Import}_{u,c,t}) = \sum_{\tau=2012}^{2022} \beta_{\tau} \times \mathbb{1}(t = \tau) \times \omega_{u,d} + \alpha_{u,d,c} + \eta_{u_{hs2},c,t} + \epsilon_{u',d'} \quad (4)$$

Import of a 4-digit upstream goods  $u$ , into country  $c$  in year  $t$  The  $\omega_{u,d}$  is our binary linkage indicator that captures whether a specific upstream good  $u$  serves as an input to downstream good  $d$ :

$$\omega_{u,d} = \begin{cases} 1 & \text{if input } u \text{ is a an AIPNET input used to produce } d \\ 0 & \text{otherwise} \end{cases}$$

Global trend towards increasing imports of goods with many AIPNET downstream linkages since 2016

# Cross-Country Evidence: Global Trade Dynamics

- ▶ Uses exporter×importer×product trade data for 120 countries, 2010-2022
- ▶ Study broad trends by network centrality
- ▶ Econometric specification:
  - ▶ Each observation is a triple:  
 $\{upstream = i, downstream = j, destination = c\}$
  - ▶ Price shock dummy variables:  $S = \{0, 1\}$
  - ▶ Network Linkages:  $W_{ij} = \{1, 0\}$
  - ▶ Doubly robust network inference estimator
  - ▶ Highly saturated controls

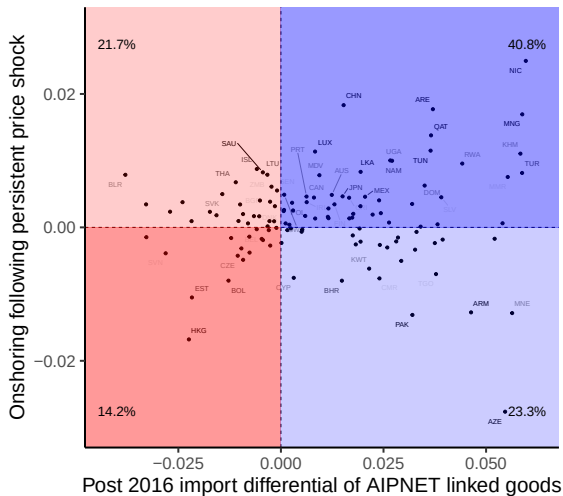
$$\begin{aligned}\log(\text{Import}_{u,c,t}) = & \xi_{c,d} \times \text{Shock}_{d,c,t} \\ & + \eta_{c,u} \times \text{Shock}_{d,c,t} + \alpha_{u,d,c} + \eta_{u_{hs2},c,t} + \epsilon_{u',d'}\end{aligned}$$

**Table 3:** Impact of persistent supply shocks affecting downstream goods prices on imports of upstream goods

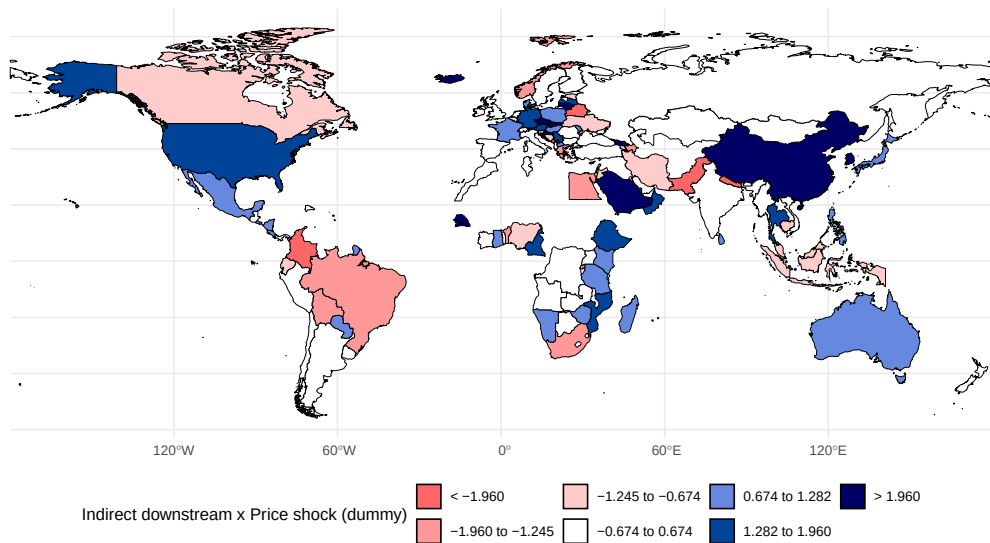
|                                                        | (1)                   | (2)                    | (3)                   | (4)                                     |
|--------------------------------------------------------|-----------------------|------------------------|-----------------------|-----------------------------------------|
| <i>Dependent variable</i>                              | <i>log(import)</i>    |                        | <i>Import &gt; 0</i>  |                                         |
| Post 2016 × AIPNET linkage                             | 0.0092***<br>(0.0027) |                        | 0.0013***<br>(0.0003) |                                         |
| AIPNET linkage × Indirect upstream price shock (dummy) |                       | 0.0014**<br>(0.0007)   |                       | 0.0003***<br>(6.32 × 10 <sup>-5</sup> ) |
| AIPNET linkage × Direct own price shock (dummy)        |                       | -0.0348***<br>(0.0081) |                       |                                         |
| R <sup>2</sup>                                         | 0.94329               | 0.94421                | 0.74324               | 0.74622                                 |
| No. of dyad FE                                         | 171,179,618           | 167,866,385            | 174,364,440           | 171,163,960                             |
| No. of time FE                                         | 121,433               | 121,433                | 121,440               | 121,440                                 |
| Observations                                           | 1,818,906,530         | 1,727,632,808          | 1,916,673,000         | 1,818,407,660                           |
| <b>Regression specification:</b>                       |                       |                        |                       |                                         |
| Country × Dyad                                         | X                     | X                      | X                     | X                                       |
| Country × HS2 × Time                                   | X                     | X                      | X                     | X                                       |

Notes: Table presents regression results documenting the impact of persistent price shocks on downstream goods on upstream imports. Standard errors provided in parentheses are clustered at the HS2 by HS2 pair level with stars indicating \*\*\* p < 0.01, \*\* p < 0.05, and \* p < 0.1.

Countries exhibiting post 2016 differential increase in goods with many AIPNET linkages also exhibit notable onshoring response following downstream supply shocks

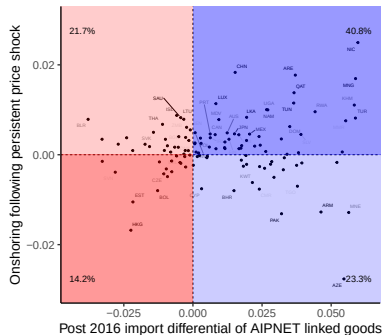


# Estimated supply-shock induced onshoring response across countries



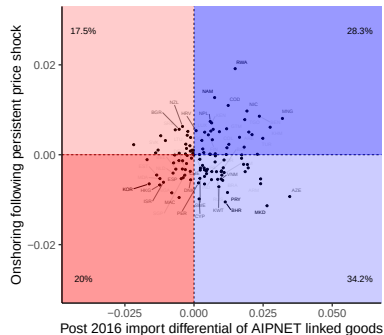
# Evolution of coefficient length as function of perturbation

## Main AIPNET



Statistical significance    20%    10%    5%    1%

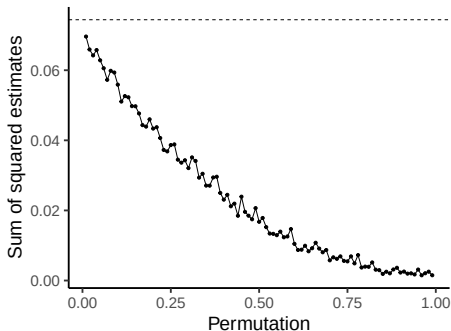
## Perturbation 50%



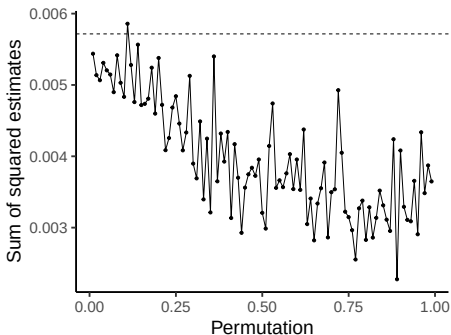
Statistical significance    20%    10%    5%

# Evolution of coefficient length as function of perturbation

Post 2016 coefficient  $||\hat{\beta}_c||_{\mathcal{L}_2}$



Onshoring coefficient  $||\hat{\beta}_{c,d}||_{\mathcal{L}_2}$



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A bit of speculation

# Qatar Case Study: Blockade Impact on Trade

- ▶ Analysis of the 2017 Qatar diplomatic crisis and trade blockade
- ▶ Utilizes admin data from customs authority on monthly trade
- ▶ Focus on changes in import patterns and onshoring efforts
- ▶ Examination of direct and indirect effects on trade

# Example of Good that was localized

**Capital equipment**

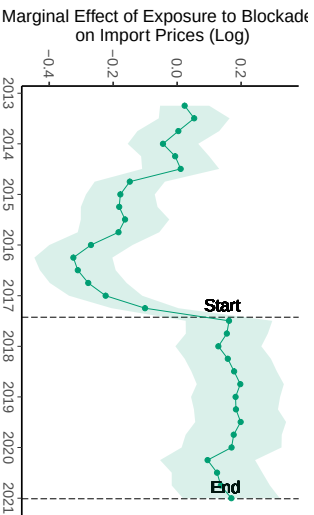


**Capital equipment**

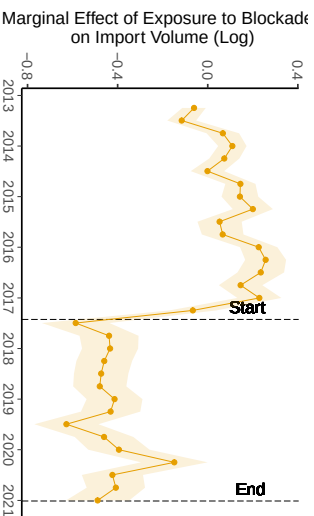


# Blockade Dramatically Shifted Trade Flows

## Import Prices

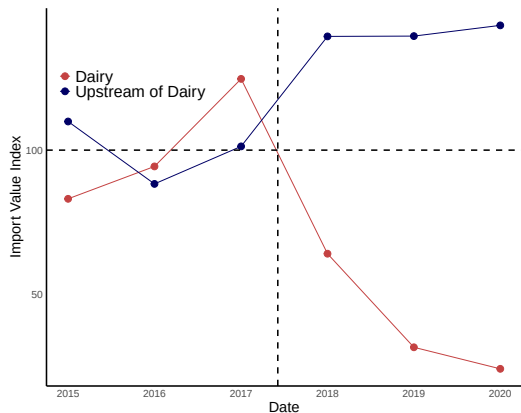


## Import Volume

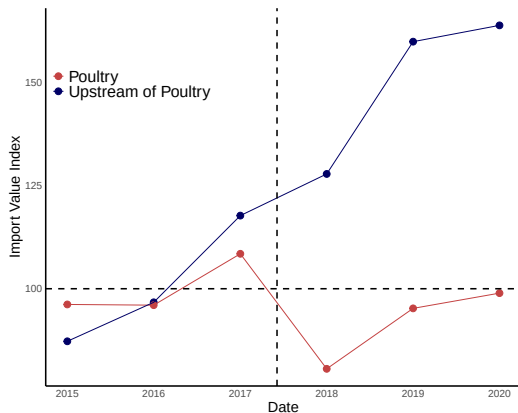


# Examples of onshoring evidence of onshoring measured through AIPNET linkages in Qatar case

## Dairy



## Poultry



# Unpacking the Import Equation

$$\ln(\text{Import}_{jt}) = \beta_1(E_i \times \text{Post}_t) + \beta_2(E_i \times \text{Post}_t \times W_{ij}) + \alpha_{ij} + \gamma_{jt} + \epsilon_{ijt}$$

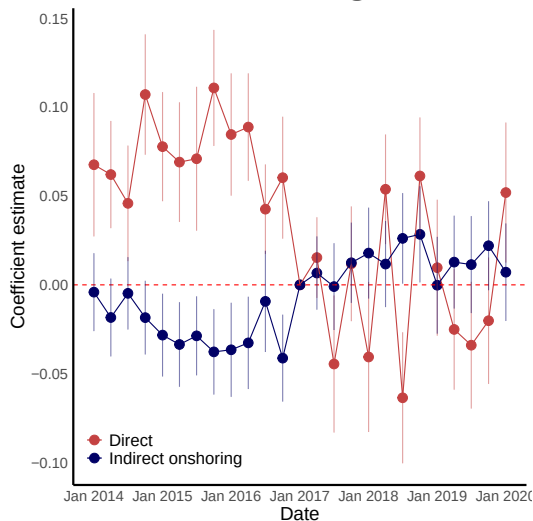
- ▶  $E_i$ : Exposure of product  $i$  to blockade based on pre-blockade import share
- ▶  $W_{ij}$ : Dummy for whether  $i$  is used as an input to produce  $j$
- ▶  $\beta_1$ : Direct effect of blockade exposure
- ▶  $\beta_2$ : Indirect effect of blockade exposure

# Pooled Onshoring Regression for Qatar

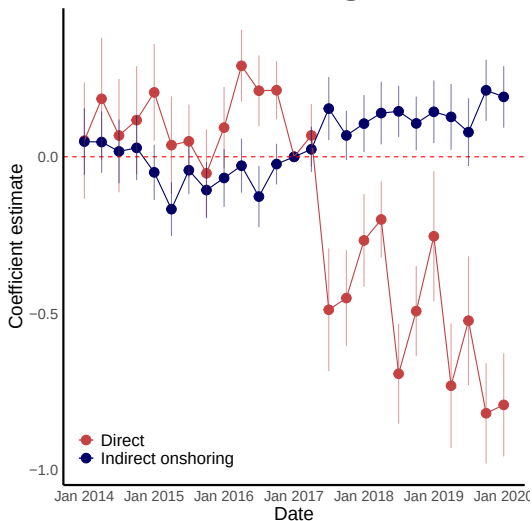
|                                       | (1)                      | (2)                   | (3)                    | (4)                       | (5)                  | (6)                    |
|---------------------------------------|--------------------------|-----------------------|------------------------|---------------------------|----------------------|------------------------|
| <i>Dependent variable</i>             | upstream good import > 0 |                       |                        | log(upstream good import) |                      |                        |
| <i>Panel A: HS4 x quarterly panel</i> |                          |                       |                        |                           |                      |                        |
| Blockade × Direct Exposure            | -0.0685***<br>(0.0120)   |                       | -0.0755***<br>(0.0142) | -0.5595***<br>(0.0718)    |                      | -0.5809***<br>(0.0718) |
| Blockade × Downstream Exposure        |                          | 0.0267***<br>(0.0084) | 0.0286***<br>(0.0075)  |                           | 0.0881**<br>(0.0409) | 0.1616***<br>(0.0430)  |
| R <sup>2</sup>                        | 0.66689                  | 0.66701               | 0.66743                | 0.86734                   | 0.86695              | 0.86815                |
| Observations                          | 991,150                  | 976,650               | 976,650                | 787,950                   | 776,058              | 776,058                |
| <i>Panel B: HS6 x quarterly panel</i> |                          |                       |                        |                           |                      |                        |
| Blockade × Direct Exposure            | -0.0297**<br>(0.0120)    |                       | -0.0379***<br>(0.0126) | -0.4081***<br>(0.0521)    |                      | -0.4154***<br>(0.0531) |
| Blockade × Downstream Exposure        |                          | 0.0138*<br>(0.0073)   | 0.0082<br>(0.0106)     |                           | 0.0204<br>(0.0370)   | 0.0605<br>(0.0380)     |
| R <sup>2</sup>                        | 0.56880                  | 0.56778               | 0.55651                | 0.78021                   | 0.77878              | 0.77958                |
| Observations                          | 9,640,300                | 9,405,825             | 9,405,825              | 5,833,222                 | 5,699,916            | 5,699,916              |
| Dyad FE                               | X                        | X                     | X                      | X                         | X                    | X                      |
| Time FE                               | X                        | X                     | X                      | X                         | X                    | X                      |

# Event-study style regression with flexible timing

## Extensive margin



## Intensive margin



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A bit of speculation

# Briefly sketch out five other applications of AIPNET

Broad range of applications for Treasury adjacent

- ▶ Tariff schedules along value chains
- ▶ Designing retaliation along value chains
- ▶ Sanctions and trade in capabilities
- ▶ Local variety version of AIPNET
- ▶ Hypothetical AIPNET in new energy paradigm
- ▶ Rethinking procurement processes

→ AIPNET is useful to understand what is going on around the world and why, in particular in a geoeconomic context.

# Industrial policy along value chains

Chinese post WTO tariffs: export taxes on raw materials created localisation of value chains *specifically for rare earths*

## Dairy



### The persistence of trade policy in China after WTO accession

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F14  
O13  
O24

Keywords:  
China  
WTO  
Trade policy  
Tariffs  
Export restrictions  
Export taxes

#### ABSTRACT

Import tariffs have fallen steeply worldwide over the last several decades, but has trade policy persisted through a rise in the use of other instruments? I study this question in the context of China's 2001 accession to the World Trade Organization, using panel data on Chinese export policies. I find that after its entry into WTO, the distribution of China's export restrictions across industries increasingly resembles the inverse of its pre-WTO import tariff schedule. The evidence suggests that increases in export restrictions are likely to have partly restored China's pre-WTO trade policy.

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## Continuity

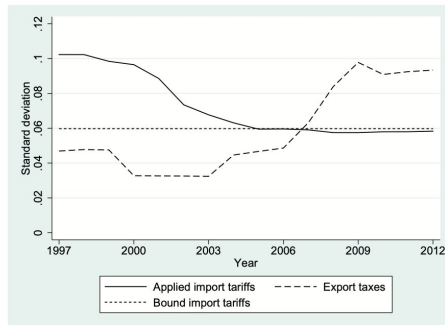
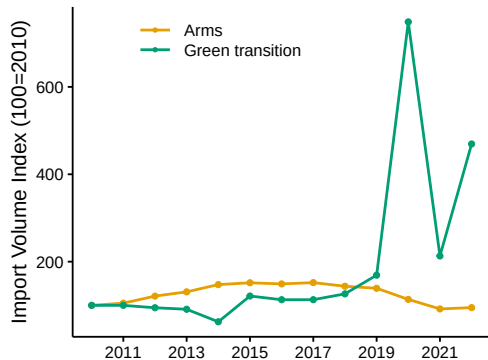


Fig. 1. Standard deviation of China's applied and bound import tariffs and export tax equivalents of export VAT rebate policies and export duties across nonagricultural products, 1997 to 2012.

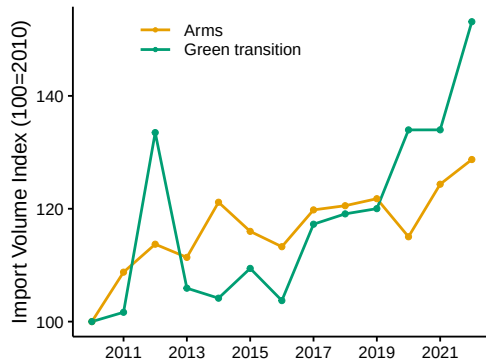
→ study China's tariff and tax positions along known value chains

# Forensic trade monitoring through AIPNET linkages

## Final use goods



## AIPNET linked inputs



# Designing tariff retaliation along value chains

## EU Regulation 654:

*“Commercial policy measures [...] shall be determined on the basis of the following criteria, in light of available information and of the Union’s general interest:*

*(a) **effectiveness of the measures in inducing compliance of third countries** with international trade rules;*

*(b) potential of the measures to **provide relief to economic operators within the Union** affected by third country measures;*

*(c) **availability of alternative sources of supply** for the goods or services concerned, in order to avoid or minimise any negative impact on downstream industries, contracting authorities or entities, or final consumers within the Union;”*

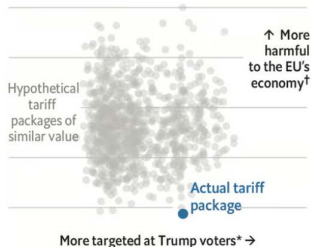
→ AIPNET allows us to think about retaliation design incorporating value chains

# Designing tariff retaliation along value chains

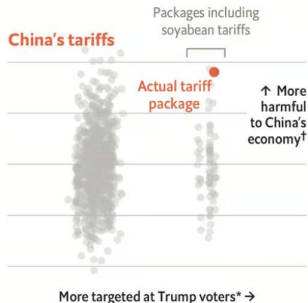
**The EU tried to minimise the harm of its tariffs on its own economies. China showed no such concern**

Political impact and domestic economic cost of tariff packages  
Actual v 1,000 simulated alternatives

## The EU's tariffs



## China's tariffs

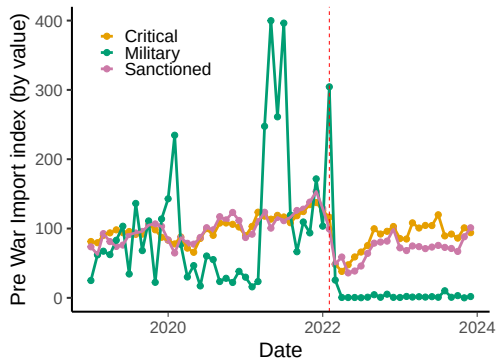


\*Impact of change in Republican presidential vote share from 2012-16 on probability of a county being in the top 10% of exposure to retaliatory tariffs †Share of retaliating country's total imports of targeted goods that come from the US  
Source: "Tariffs and Politics: Evidence from Trump's Trade Wars", working paper by T. Fetzer and C. Schwarz, 2019

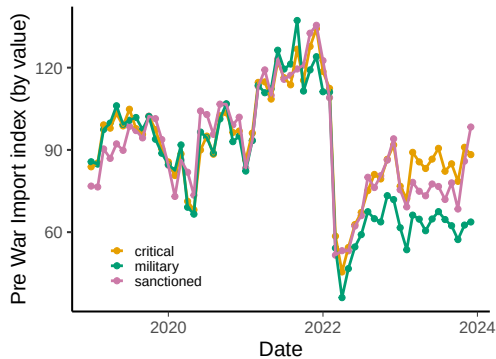
→ 2018 escalation provided window into studying retaliation responses revealing sophisticated political targeting

# Sanctions and trade in capabilities

## Final use goods



## AIPNET linked inputs



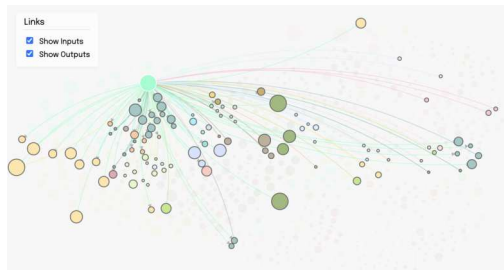
→ AIPNET can be leveraged for forensic trade analysis in terms of trade in *capabilities* as highlighted by e.g. EU sanctions on Russia

# Hypothetical Global Production Network

## Full network



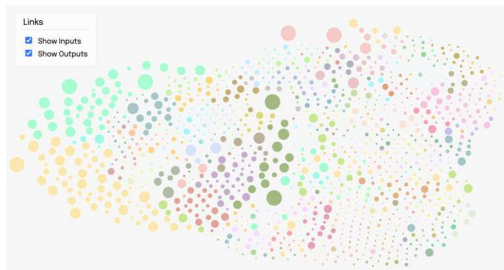
## Circuits



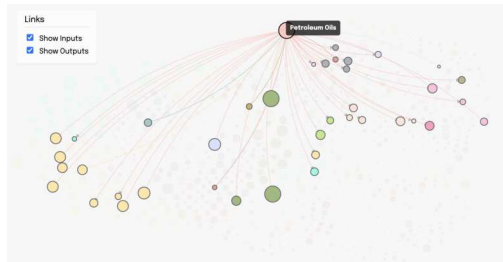
→ use AI reasoning to explore how global production may be reshaped in light of renewable energy transition benefiting countries around the equator

# Hypothetical Global Production Network

## Full network



## Crude oil

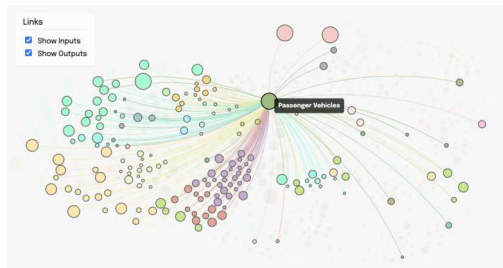


# Hypothetical Global Production Network

## Full network

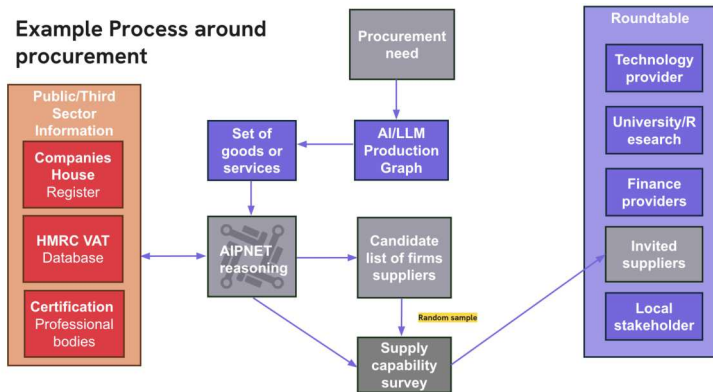


## Passenger vehicles



→ reduction in international trade of crude oil mechanically implies global rebalancing of power

# Leveraging AIPNET to reshape procurement or technology transfer



→ can leverage public knowledge graph built on public data to streamline procurement

# Outline

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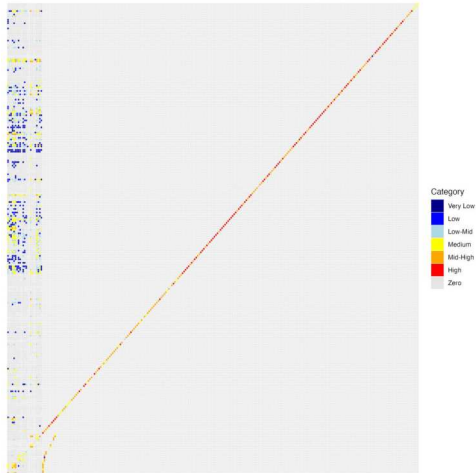
Applications of AIPNET in a Fragmenting World

A bit of speculation

If we get here...

- ▶ Then it has been a long journey

# Topology of Societal Organisation



## Key Insight

Input-output tables may be key to understanding societal organisation

# Common Applications of LLMs in Applied Economics

- ▶ **Data categorization or classification** – applying of *nomenclatures*
- ▶ **Information retrieval applications** – retrieving a *needle from a haystack*
- ▶ **Dimensionality reduction** – summarization of *large datasets*
- ▶ **Dataset construction** – leaning on embodied knowledge in LLMs
- ▶ **Retrieval augmented dataset construction** – prompt and context into context
- ▶ **Reasoning tasks** – complex bipartite matching tasks with incomplete information

# Example: Data categorization or classifications

## Political Expression of Academics on Twitter

Prashant Garg<sup>1</sup> and Thiemo Fetzer<sup>2,3</sup>

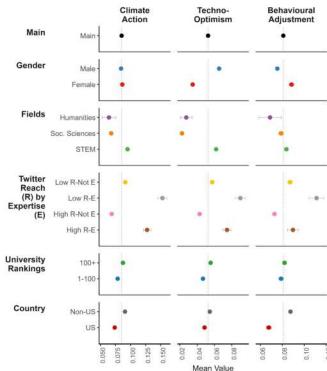
<sup>1</sup>Department of Economics and Public Policy, Imperial College London,  
London, United Kingdom

<sup>2</sup>Department of Economics, University of Warwick, Coventry, United Kingdom

<sup>3</sup>Department of Economics, University of Bonn, Bonn, Germany

### Abstract

Academics play a vital role in the generation and dissemination of knowledge, ideas and narratives. Social media provide new, more direct ways of science communication. Yet, since not all academics engage with social media, the sample that does so may have an outsize influence on shaping public perceptions of academia through the set topics they engage with and their style and tone of communication. We describe patterns in academics' expression online using an international dataset covering nearly 100,000 scholars linking their Twitter content to academic records. We document large and systematic variation in politically salient academic expression concerning climate action, cultural, and economic concepts. We show that US academics often diverge from the US Twitter population at large in topic focus and style, although academics are not necessarily more extreme in their beliefs. Future work should examine potential impacts on public trust and the reasons why academics express themselves politically on social media.



→ forthcoming in *Nature: Human Behavior* with interactive website on [academicexpression.online](https://academicexpression.online).

# Example: Dataset construction

## AI-Generated Production Networks: Measurement and Applications to Global Trade

Thiemo Fetzter<sup>\*</sup>  
Peter John Lambert<sup>†</sup>  
Bennet Feld<sup>‡</sup>  
Prashant Garg<sup>§</sup>

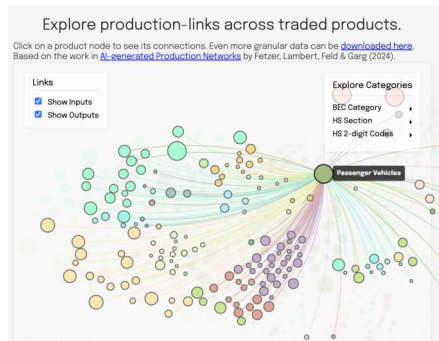
November 18, 2024

### Abstract

This paper leverages generative AI to build a network structure over 5,000 product nodes, where directed edges represent input-output relationships in production. We layout a two-step 'build-prune' approach using an ensemble of prompt-tuned generative AI classifications. The 'build' step provides an initial distribution of edge-predictions, the 'prune' step then re-evaluates all edges. With our AI-generated Production Network (AIPNET) in toe, we document a host of shifts in the network position of products and countries during the 21st century. Finally, we study production network spillovers using the natural experiment presented by the 2017 blockade of Qatar. We find strong evidence of such spill-overs, suggestive of on-shoring of critical production. This descriptive and causal evidence demonstrates some of the many research possibilities opened up by our granular measurement of product linkages, including studies of on-shoring, industrial policy, and other recent shifts in global trade.

**Keywords:** SUPPLY-CHAIN NETWORK ANALYSIS, LARGE LANGUAGE MODELS, ON-SHORING, INDUSTRIAL POLICY, TRADE WARS, ECONOMETRICS-OF-LLMs

**JEL Classification:** F14, F23, L16, F52, O25, N74, C81



→ presented to policy audiences and Ministries with interactive website on [aipnet.io](http://aipnet.io).

# Example: Retrieval augmented dataset construction

## Causal Claims in Economics\*

Prashant Garg

Thiemo Fetzer<sup>†</sup>

January 14, 2025

[Click here for the latest version](#)

### Abstract

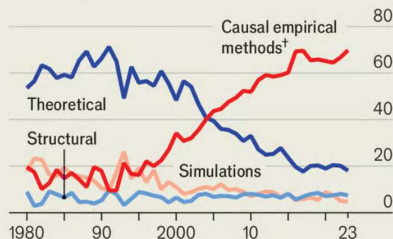
We analyze over 44,000 NBER and CEPR working papers from 1980–2023 using a custom language model to construct knowledge graphs that map economic concepts and their relationships. We distinguish between general claims and those documented via causal inference methods (e.g., DiD, IV, RDD, RCTs). We document a substantial rise in the share of causal claims—from roughly 4% in 1990 to nearly 28% in 2020—reflecting the growing influence of the “credibility revolution.” We find that causal narrative complexity (e.g., the depth of causal chains) strongly predicts both publication in top-5 journals and higher citation counts, whereas non-causal complexity tends to be uncorrelated or negatively associated with these outcomes. Novelty is also pivotal for top-5 publication, but only when grounded in credible causal methods: introducing genuinely new causal edges or paths markedly increases both the likelihood of acceptance at leading outlets and long-run citations, while non-causal novelty exhibits weak or even negative effects. Papers engaging with central, widely recognized concepts tend to attract more citations, highlighting a divergence between factors driving publication success and long-term academic impact. Finally, bridging under-explored concept pairs is rewarded primarily when grounded in causal methods, yet such gap filling exhibits no consistent link with future citations. Overall, our findings suggest that methodological rigor and causal innovation are key drivers of academic recognition, but sustained impact may require balancing novel contributions with conceptual integration into established economic discourse.

**Keywords:** KNOWLEDGE GRAPH, CREDIBILITY REVOLUTION, CAUSAL INFERENCE, NARRATIVE COMPLEXITY, NOVELTY, LARGE LANGUAGE MODELS

**JEL Classification:** A10, B41, C18, C80, D83

## Data deluge

NBER and CEPR working papers\*, % of total  
By method



\*44,800 papers published by National Bureau of Economic Research and Centre for Economic Policy Research

<sup>†</sup>Includes instrumental variables, randomised controlled trials, etc  
Source: “Causal claims in economics”,  
by P. Garg and T. Fetzer, 2025 (pre-print)

→ rethinking how we represent papers

# Example: Reasoning tasks

Has polarization accelerated or has *nuance* increased? \*

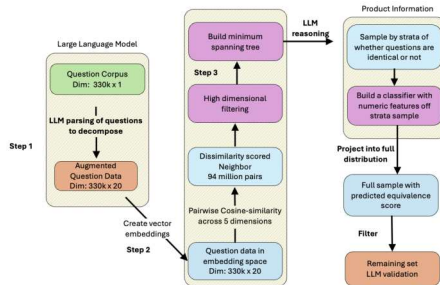
Thiemo Fetzer <sup>†</sup>

May 28, 2025

## Abstract

What do policy makers want to know, and when? This paper leans on 4000+ public opinion polling databases carried out from the 1940s to 2020. It develops a pipeline that aligns opinion polling questions along with the underlying micro data using vector embeddings, semantic search and reasoning models to arrive at a large sample of opinion polling questions that have been consistently asked across different decades. Using this data, I document that the relative speed of partisan polarization – across broad set of time-varying and time-invariant issues – has drastically increased since the 2000s. Using a set of econometric exercises, this is causally attributed to the rapid rollout of social media. Yet, exploration *within issue* highlights a high degree of *nuance* in the extent of polarization that may be masked in popular debate, possibly highlighting that this increase in polarization may be much more driven by *perceptions*.

**Keywords:** PUBLIC OPINION, POLARIZATION, SOCIAL MEDIA, ARTIFICIAL INTELLIGENCE APPLICATIONS



→ agentic AI with reasoning capabilities to align 4000+ opinion polling micro datasets

# Conclusion

- ▶ We construct and validate the AI-built Production Network (AIPNET)
- ▶ Allows us to study vertical substitution up the value-chain
- ▶ Three main results:
  - ▶ Global trade patterns shifting towards upstream goods
  - ▶ Structural breaks in unit-prices correlate with vertical substitution
  - ▶ Exogenous blockade event leads to onshoring via upstream substitution
- ▶ Next steps:
  - ▶ 'Place-based AIPNET' ie Local Production Networks
  - ▶ Public data available on AIPNET website

# Bibliography