ECO 2302 Research Proposal

Role of Networks in Structural Transformation

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1 Motivation

Structural transformation is a robust feature of economic development. In literature, there are two major forces driving structural transformation: substitution effect and income effect: (Herrendorf et al., 2014).

- Substitution effect: Change in relative sectoral productivity → Change in relative sectoral prices → Change in sectoral value-added/employment share
- Income effect: Difference in income elasticity across sectors → When income changes, sectoral expenditure share changes → Change in sectoral value-added/employment share

However, there are still works to be done to provide further understand on the determinants of sectoral productivity. There are many different ways in literature to explore sectoral productivity determinants (such as firm heterogeneity, misallocation).

Production network is an important feature of the economy that may not only provide an better understanding on sources driving sectoral productivity but also bring new dimensions into analysis of structural transformation.

In literature, there have been a few papers on the role of network in aggregate income and growth.

- Grobovšek (2017) investigates the role production network with broad sector (goods and services) in determining aggregate income level. The paper reports findings that poor countries tend to have low TFPs in intermediate goods production and consequently results in low labor productivity in goods sector.
- Duarte and Restuccia (2020) employ the input-output linkages in services sector to estimate income elasticity of different types of services and find an important role of network in accounting for aggregate income level.
- Fadinger et al. (2021) study the cross-country income differences via network of 35 industries. They find that aggregate income depends on first and second moments of the distribution of input-output (IO) multipliers. Moreover, there significant difference in IO multipliers distribution between rich and poor countries: poor countries tend to have very few sectors with high IO multiplier.

There are several research questions in this proposal:

- How is sectoral productivity level/growth determined and connected via a network?
- How does the role of income effect change in a model with production network?
- Can cross-country differences in network quantitatively explain cross-country heterogeneous structural transformation patterns?
- Extension to open economy: How does sectoral productivity shock to one country affect the others?

2 Model

Model comprise of production feature in Acemoglu et al. (2012) and demand feature of nonhomothetic CES preference in Comin et al. (2021).

2.1 Production Technology

Economy consists of N sectors with production technology

$$X_i = T_i \left(\frac{L_i}{1-\gamma_i}\right)^{1-\gamma_i} \left(\frac{M_i}{\gamma_i}\right)^{\gamma_i}$$
$$\text{s.t.} \quad M_i = \prod_{j=1}^{N} \left(\frac{X_{ij}}{\beta_{ij}}\right)^{\beta_{ij}}, \quad \text{with} \quad \sum_{j=1}^{N} \beta_{ij} = 1$$

Given wage $w = 1$ and prices P_i , firms choose L_i and X_{ij} to maximize profit.

FOCs imply

$$L_i = (1-\gamma_i) P_i X_i$$
$$P_j X_{ij} = \gamma_i \beta_{ij} P_i X_i$$

Plugging into production function yields

$$X_i = T_i P_i X_i \prod_{j=1}^{N} P_j^{-\gamma_i \beta_{ij}}$$
$$\Rightarrow \quad P_i = \frac{1}{T_i} \prod_{j=1}^{N} P_j^{\gamma_i \beta_{ij}}$$

Let p_i and t_i denote the log of P_i and T_i. Then,

$$p_i = -t_i + \gamma_i \sum_{j=1}^{N} \beta_{ij} p_j$$

Denote $\boldsymbol{p}$, $\boldsymbol{t}$ and $\boldsymbol{\gamma}$ be the vector of p_i, t_i and γ_i. Let $\boldsymbol{\beta}$ be matrix of β_{ij}. We can solve for prices as function of TFP

$$\boldsymbol{p} = -\boldsymbol{t} + \boldsymbol{\gamma}' \boldsymbol{\beta} \boldsymbol{p}$$
$$\Rightarrow \quad \boldsymbol{p} = (\boldsymbol{\gamma}' \boldsymbol{\beta} - I)^{-1} \boldsymbol{t}$$

In the network, TFP in sector j also affects price in sector i. Define $\mathbf{\Omega} \equiv (\boldsymbol{\gamma}'\boldsymbol{\beta} - I)^{-1}$. We will have

$$p_i = \sum_{j=1}^{N} \mathbf{\Omega}_{ij} t_j$$

$$\text{or} \quad P_i = \prod_{j=1}^{N} T_j^{\mathbf{\Omega}_{ij}}$$

2.2 Comparison to Labor Productivity

Define Y_i as value-added in sector i. Nominal value-added can be derived as

$$P_i Y_i \equiv P_i X_i - \sum_{j=1}^{N} P_j X_{ij} = (1 - \gamma_i) P_i X_i = L_i$$

As a result, we have

$$Y_i = \frac{L_i}{P_i}$$

Let labor productivity in sector i be A_i. Then, we have

$$A_i = \frac{Y_i}{L_i} = \frac{1}{P_i}$$

The relative price or relative labor productivity drives the structural change pattern.

With the networks, we can then decompose sectoral labor productivity into components from other sectoral TFPs. For instance, in an economy, if there's a sector i with strong linkage with other sectors, TFP_i growth is really important in driving other sectoral labor productivity growth (affect Structural Change).

2.3 Household's Problem

Household with population normalized to 1 have nonhomothetic CES preference over N goods implicitly defined

$$\left[\sum_{i=1}^{N} \varphi_i^{\frac{1}{\sigma}} \left(\frac{C_i}{U^{\epsilon_i}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} = 1$$

Homothetic CES preference is special case when $\epsilon_i = 1 \quad \forall i = 1, ..., N$.

Given wages $w = 1$ and prices P_i, household chooses C_i to maximize utility.

$$\underset{\{C_i\}_{i=1}^N}{max} \quad U(C_1, ..., C_N) \quad \text{s.t.} \quad \sum_{i=1}^{N} P_i C_i = 1$$

FOCs yields

$$\frac{P_i C_i}{P_j C_j} = \frac{\varphi_i}{\varphi_j} \left(\frac{P_i}{P_j}\right)^{1-\sigma} U^{\epsilon_i - \epsilon_j}$$

Nominal consumption share depends on relative prices across sectors and income level (similar to standard structural change models). Given prices, we can solve for C_i and U based on FOCs, budget constraint and definition of U.

Labor market clearing

$$\sum_{i=1}^{N} L_i = 1$$

Goods market clearing

$$X_i = C_i + \sum_{j=1}^{N} X_{ji}$$

A different feature in this model is that consumption is different from value-added

$$\text{Value-Added:} \quad Y_i = X_i - \sum_{j=1}^{N} \frac{P_j X_{ij}}{P_i}$$

$$\text{Consumption:} \quad C_i = X_i - \sum_{j=1}^{N} X_{ji}$$

In equilibrium, we have consumption C_i can be derived from household's problem (expenditure share depends on relative prices). To derive gross output and value-added, we use goods market clearing condition

$$P_i X_i = P_i C_i + \sum_{j=1}^{N} P_i X_{ji} = P_i C_i + \sum_{j=1}^{N} \gamma_j \beta_{ji} P_j X_j$$

We can write in matrix form and solve for $P_i X_i$ as a function of $P_i C_i$. Sectoral gross output and value-added are also dependent from cross-sector consumption.

Labor share is equal to value-added share (proportional to relative gross output)

$$\frac{L_i}{L_j} = \frac{(1-\gamma_i)X_i}{(1-\gamma_j)X_j}$$

Labor share does not just depend on sectoral expenditure. This may have different implication for income effects. A sector (high-skilled services like finance) rise at high level level of income may not just be due to its rising income elasticity but could also come from the change in sector's linkages when income rises.

In a network, high labor share in 1 sector could be a result of

1. High final expenditure demand
2. Sell intensively to other sectors with high expenditure demand

3 Implications of Network

1. Decompose labor productivity into multiple components of TFPs across sectors

2. Cross-country difference in network structural may explain cross-country difference in relative sectoral labor productivity and structural transformation pattern → Low labor productivity growth in 1 sector may be the result of weak linkage with high TFP growth sectors.

3. May have different implication for income effect channel because labor share is a function of value-added share (which is not just sectoral expenditure share but as a weighted average of expenditure across sectors)

4. Another interesting feature we can look at is whether production network is subject to income level. This may be another channel beside substitution and income effect channels leading to structural transformation over stages of development.

   These are the potential roles of production network in explaining sectoral labor productivity and structural transformation patterns. However, to quantify the impact of network, we need to perform empirical investigation.

4 Data and Expected Results

In order to investigate the role of network in determining structural transformation patterns, I will use World Input-Output Database (WIOD). I will first document stylized facts on production network across economies at different stage of development. The next step is to study how the network contributes to explain cross-country difference in sectoral labor productivity and sectoral employment share.

One expected result is cross-country difference in production network. Low-income countries are expected to use less intermediate input in production. This is expected to result in low sectoral productivity due to small spillover effect from high productivity sectors (mining and manufacturing industries). Another result that we may expect is different sectoral income elasticity from standard structural change models. As discussed above, besides the substitution and income effect, production network also has a role in structural transformation. However, it is an empirical question to quantitatively measure the role of network in explaining structural transformation.

References

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