Population Size Effects in Structural Development

Oksana Leukhina and Stephen Turnovsky

Paris, 2015
Pre-crisis Observations

1 Motivating Evidence
Pre-crisis Observations

1. Motivating Evidence
2. Analytical Framework and Results
Pre-crisis Observations

1. Motivating Evidence
2. Analytical Framework and Results
Structural Development of England

Nonfarm Labor/Total

Year

Fraction of nonfarm labor in total labor

1550 1600 1650 1700 1750 1800 1850 1900

0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Oksana Leukhina and Stephen Turnovsky (Population Size Effects in Structural Development)
Structural Development of England

Nonfarm Output/Total

Year

Fraction of nonfarm output in total output

1550 1600 1650 1700 1750 1800 1850 1900

0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Oksana Leukhina and Stephen Turnovsky
Population Size Effects in Structural Development
Paris, 2015
Structural Development of England

Indicators of Real GDP/Capita

Year
Index

1550 1600 1650 1700 1750 1800 1850 1900
4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6

In(Index of Real GDP/Capita)

Year

1550 1600 1650 1700 1750 1800 1850 1900
Structural Development of England

Farm Price / Nonfarm Price Index

<table>
<thead>
<tr>
<th>Year</th>
<th>p_A / p_M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550</td>
<td>0.5</td>
</tr>
<tr>
<td>1600</td>
<td>1</td>
</tr>
<tr>
<td>1650</td>
<td>1.5</td>
</tr>
<tr>
<td>1700</td>
<td>2</td>
</tr>
<tr>
<td>1750</td>
<td>2.5</td>
</tr>
<tr>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td></td>
</tr>
<tr>
<td>1900</td>
<td></td>
</tr>
</tbody>
</table>
Structural Development of England

Investment Rate

Year

Investment Rate

Year

1550 1600 1650 1700 1750 1800 1850 1900

0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1 0.11 0.12 0.13

Structural Development of England

Log of Population Size

<table>
<thead>
<tr>
<th>Year</th>
<th>Log(Population Size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550</td>
<td>15</td>
</tr>
<tr>
<td>1600</td>
<td>15.5</td>
</tr>
<tr>
<td>1650</td>
<td>16</td>
</tr>
<tr>
<td>1700</td>
<td>16.5</td>
</tr>
<tr>
<td>1750</td>
<td>17</td>
</tr>
<tr>
<td>1800</td>
<td>17.5</td>
</tr>
<tr>
<td>1850</td>
<td>18</td>
</tr>
</tbody>
</table>

Oksana Leukhina and Stephen Turnovsky
Typically focus on a very specific channel

- gross substitutes: faster productivity growth sector pulls labor in [e.g. Lewis (1954), Hansen and Prescott (2000), Doepke (2004), Bar and Leukhina (2008)]
Shortcomings

- No consensus on the most appropriate channel or combination
- Population size effects have not been properly investigated
  - Two references in the literature to population size effects
    1. Gollin and Rogerson (JED, 2014) highlight the adverse effect of population size on $L_m/L$ due to the presence of subsistence consumption.
    2. Bar and Leukhina (RED, 2010) highlight the positive effect of population size on $L_m/L$ due to a greater intensity of labor in manufacturing.
- However, in many models of structural development, population size enters the model in a neutral way. We will argue such frameworks are empirically implausible.
What We Do

- Examine analytically the effects of population size on structural development in a parsimonious general equilibrium two sector growth model.
  - Important: general production functions, general utility function.
- Study the effects of population change on structural development in the case of England.
Model

- Standard Dynamic GE model
- There is a large number of identical infinitely-lived families of mass 1, each composed of $L_t$ identical individuals at time $t$.
- Two types of goods:
  1. Farm good is produced with capital, labor and land
  2. Nonfarm good is produced with capital and labor only.
Nonfarm good is numeraire
$F, G$ are homogeneous of degree 1

- Nonfarm sector solves

$$\max_{K_{M,t}, L_{M,t}} F_t (K_{M,t}, L_{M,t}) - w_t L_{M,t} - r_t K_{M,t}$$
Nonfarm good is numeraire
\( F, G \) are homogeneous of degree 1

- Nonfarm sector solves
  \[
  \max_{K_{M,t}, L_{M,t}} F_t (K_{M,t}, L_{M,t}) - w_t L_{M,t} - r_t K_{M,t}
  \]

- Farm sector solves
  \[
  \max_{K_{A,t}, L_{A,t}, \Lambda_t} p_t G_t (K_{A,t}, L_{A,t}, \Lambda_t) - w_t L_{A,t} - r_t K_{A,t} - \rho_t \Lambda_t
  \]
Given \( \{ w_t, r_t, \rho_t, p_t \}_{t=0}^{\infty} \), families make consumption and capital accumulation choices to solve

\[
\max_{\{a_t, c_t, k_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t L_t u(a_t - \bar{a}, c_t) \quad \text{subject to}
\]

\[
p_t a_t + c_t + k_{t+1} \frac{L_{t+1}}{L_t} - (1 - \delta) k_t = r_t k_t + w_t + \rho_t \lambda_t, \quad \text{for all } t
\]

\[
a_t, c_t, k_{t+1} \geq 0, \quad \text{for all } t
\]

\[
k_0, \lambda_0 \text{ given}
\]
To capture the expansion of trade, we assume that imports of food grow in accordance with the data, $\{M_t\}$.
The amount of exports $\{X_t\}$ adjusts endogenously to ensure a trade balance,

$$X_t = p_t M_t.$$
Market Clearing

\[ L_{M,t} + L_{A,t} = L_t, \]
\[ K_{M,t} + K_{A,t} = K_t. \]
\[ \Lambda_t = \Lambda. \]
\[ C_t + K_{t+1} - (1 - \delta)K_t + X_t = F(K_{M,t}, L_{M,t}, t). \]
\[ A_t = G_t(K_{A,t}, L_{A,t}, \Lambda_t, t) + M_t. \]
A competitive equilibrium consists of allocations 
\( \{A_t, C_t, K_{t+1}, K_A, K_{M,t}, L_{A,t}, L_{M,t}, \Lambda_t, X_t\} \) and prices \( \{p_t, w_t, r_t, \rho_t\} \) such that

- firms’ maximization problems are solved
- families’ maximization problem is solved
- market clearing and trade balance conditions are satisfied.
Equilibrium Characterization

Families’ maximization is characterized by

\[ p_t = \frac{u_2(c_t, a_t)}{u_1(c_t, a_t)}, \]

\[ \beta (r_{t+1} + 1 - \delta) = \frac{u_1(c_t, a_t)}{u_1(c_{t+1}, a_{t+1})}. \]

Profit maximization is characterized by

\[ r_t = p_t G_1(K_{A,t}, L_{A,t}, \Lambda_t, t) = F_1(K_{M,t}, L_{M,t}, t), \]
\[ w_t = p_t G_2(K_{A,t}, L_{A,t}, \Lambda_t, t) = F_2(K_{M,t}, L_{M,t}, t), \]
\[ \rho_t = p_t G_3(K_{A,t}, L_{A,t}, \Lambda_t, t). \]

Market clearing from above.
Functional Forms

- Production technology

\[
G_t(K_{A,t}, L_{A,t}, \Lambda_t) \equiv B_{A,t} \left[ b_{A,t} K_{A,t}^{\varepsilon} + c_{A,t} L_{A,t}^{\varepsilon} + d_{A,t} \Lambda_{t}^{\varepsilon} \right]^{\frac{1}{\varepsilon}}
\]

\[
F_t(K_{M,t}, L_{M,t}) \equiv B_{M,t} K_{M,t}^{\nu} L_{M,t}^{1-\nu}
\]
Functional Forms

- **Production technology**

\[
G_t(K_{A,t}, L_{A,t}, \Lambda_t) \equiv B_{A,t} \left[ b_{A,t} K_{A,t}^\varepsilon + c_{A,t} L_{A,t}^\varepsilon + d_{A,t} \Lambda_t^\varepsilon \right]^{\frac{1}{\varepsilon}}
\]

\[
F_t(K_{M,t}, L_{M,t}) \equiv B_{M,t} K_{M,t}^v L_{M,t}^{1-v}
\]

- **Utility**

\[
U(a_t - \bar{a}, c_t) = \frac{1}{\gamma} \left[ \alpha (a_t - \bar{a}L_t)^\rho + (1 - \alpha) (c_t)^\rho \right]^{\frac{\gamma}{\rho}}
\]
Population Effect

Can be seen in the intratemporal tradeoff equation

\[
\left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{G(K_A, L_A, \Lambda, t) - aL_t}{F(K_M, L_M, t) - I_t - X_t} \right)^{\rho - 1} = p_t = \frac{F(K_M, L_M, t)}{G(K_A, L_A, \Lambda, t)}
\]

It depends crucially upon

- Elasticities of substitution in farm production \( \frac{1}{1 - \epsilon} \)
Population Effect

Can be seen in the intratemporal tradeoff equation

\[
\left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{G(K_{A,t}, L_{A,t}, \Lambda_t, t) - \bar{a}L_t}{F(K_{M,t}, L_{M,t}, t) - l_t - X_t} \right)^{\rho - 1} = p_t = \frac{F_2(K_{M,t}, L_{M,t}, t)}{G_2(K_{A,t}, L_{A,t}, \Lambda_t, t)}
\]

It depends crucially upon

- Elasticities of substitution in farm production \( \frac{1}{1 - \varepsilon} \)
- Elasticity of substitution in utility \( \frac{1}{1 - \rho} \)
Can be seen in the intratemporal tradeoff equation

\[
\left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{G(K_{A,t}, L_{A,t}, \Lambda_t, t) - \bar{a}L_t}{F(K_{M,t}, L_{M,t}, t) - I_t - X_t} \right)^{\rho - 1} = p_t = \frac{F_2(K_{M,t}, L_{M,t}, t)}{G_2(K_{A,t}, L_{A,t}, \Lambda_t, t)}
\]

It depends crucially upon

- Elasticities of substitution in farm production \( \frac{1}{1 - \epsilon} \)
- Elasticity of substitution in utility \( \frac{1}{1 - \rho} \)
- Expansion of trade
Employment Share in Manufacturing: Analytical Results

- Population Size

\[
\frac{d\hat{L}_M}{d\hat{L}} - 1 = \frac{\bar{L}_A a_\Lambda}{\kappa} \left[ (1 - \theta) \left( \frac{1}{\frac{1}{1-\varepsilon}} - \frac{1}{1-\rho (1 - \chi)} \right) - \frac{\theta}{\frac{1}{1-\rho}} \left( 1 - \frac{1}{\frac{1}{1-\varepsilon}} \right) \right]
\]

\(a_j\) – farm income shares, \(\chi = \bar{a}\tilde{L}/\bar{A}\), \(\theta = p\tilde{M}/\bar{Y}_M\)
Employment Share in Manufacturing: Analytical Results

- Population Size

\[
\frac{d\hat{L}_M}{d\hat{L}} - 1 = \frac{\tilde{L}_A a_{\Lambda}}{\kappa} \left[ (1 - \theta) \left( \frac{1}{1 - \varepsilon} - \frac{1}{1 - \rho (1 - \chi)} \right) - \frac{\theta}{1 - \rho} \left( 1 - \frac{1}{1 - \varepsilon} \right) \right]
\]

\( a_j \) – farm income shares, \( \chi = \bar{a}\tilde{L}/\tilde{A} \), \( \theta = p\tilde{M}/\tilde{Y}_M \)

- Farm Productivity

\[
\frac{d\hat{L}_M}{d\hat{B}_A} = \frac{\tilde{L}_A (1 - \theta)}{\kappa} \left[ \frac{1}{1 - \rho (1 - \chi)} - 1 \right]
\]
Employment Share in Manufacturing: Analytical Results

- **Population Size**

\[
\frac{d\hat{L}_M}{d\hat{L}} - 1 = \frac{\bar{L}_Aa_\Lambda}{\kappa} \left[ (1 - \theta) \left( \frac{1}{1-\varepsilon} - \frac{1}{1-\rho} \frac{1}{(1 - \chi)} \right) - \frac{\theta}{1-\rho} \left( 1 - \frac{1}{1-\varepsilon} \right) \right]
\]

\(a_j\) – farm income shares, \(\chi = \bar{a}\bar{L}/\bar{A},\ \theta = p\bar{M}/\bar{Y}_M\)

- **Farm Productivity**

\[
\frac{d\hat{L}_M}{d\hat{B}_A} = \frac{\bar{L}_A(1 - \theta)}{\kappa} \left[ \frac{1}{\frac{1}{1-\rho} \left( 1 - \chi \right)} - 1 \right]
\]

- **Manufacturing Productivity**

\[
\frac{d\hat{L}_M}{d\hat{B}_M} = \frac{\bar{L}_A}{\kappa s_L} \left[ \left( 1 - \theta + \frac{\theta}{1-\rho} \right) (1 - a_K) + \frac{a_K}{1-\varepsilon} \frac{1}{\frac{1}{1-\rho} \left( 1 - \chi \right)} - \frac{1}{1-\rho} \right]
\]
Calibrate the model in steady state to the (stable) 1600-1650 period.
Quantitative Investigation

- Calibrate the model in steady state to the (stable) 1600-1650 period.
- Estimate Factor Specific Technological Progress in both sectors.
Quantitative Investigation

- Calibrate the model in steady state to the (stable) 1600-1650 period.
- Estimate Factor Specific Technological Progress in both sectors.
- Feed in all the exogenous changes simultaneously into the model (population, technology, trade). Compare the model dynamics to the data.
Calibrate the model in steady state to the (stable) 1600-1650 period.

Estimate Factor Specific Technological Progress in both sectors.

Feed in all the exogenous changes simultaneously into the model (population, technology, trade). Compare the model dynamics to the data.

To assess the importance of population change – shut it down in the benchmark model.
Calibration Strategy

- Calibrate to match empirical moments during 1600-1650.
Calibration Strategy

- Calibrate to match empirical moments during 1600-1650.
- Keep parameters $\rho$ and $\varepsilon$ as well as the "target" $\chi = \tilde{a}L/\tilde{A}$ free.
Calibration Strategy

- Calibrate to match empirical moments during 1600-1650.
- Keep parameters $\rho$ and $\varepsilon$ as well as the "target" $\chi = \bar{aL}/\bar{A}$ free.
- Perform extensive sensitivity analysis with respect to $\rho$, $\varepsilon$, $\chi$. 
Calibration

Others to ensure a match with the following targets, calculated from the 1550-1650 data:

\[
\begin{align*}
&[i]: r + 1 - \delta = 1.04^5, & [ii]: \frac{P_A Y_A}{Y} = 0.65 \\
&[iii]: \frac{L_A}{L} = 0.59, & [iv]: s_L = 0.75 \\
&[v]: a_L = 0.55, & [vi]: a_K = 0.15 \\
&[vii]: \delta = 1 - 0.95^5 & [viii]: M = 0 \\
&[ix]: \chi
\end{align*}
\]
Benchmark Calibrated Parameters

- $\gamma = -1$ to ensure the elasticity of intertemporal substitution is 2
\[ \gamma = -1 \text{ to ensure the elasticity of intertemporal substitution is 2} \]

- Normalizations: \( B_{A,1650} = 1, \Lambda = 100 \)
Benchmark Calibrated Parameters

- \( \gamma = -1 \) to ensure the elasticity of intertemporal substitution is 2
- Normalizations: \( B_{A,1650} = 1, \Lambda = 100 \)
- Free critical parameters \( \rho, \varepsilon \) and critical target \( \chi \) are chosen for the benchmark model as

\( \varepsilon = 3 \) (Allen 2008, and other economic historians)
\( \rho = 1 \) (complementarity)
\( \chi = 0.3 \)
Benchmark Calibrated Parameters

- $\gamma = -1$ to ensure the elasticity of intertemporal substitution is 2
- Normalizations: $B_{A,1650} = 1$, $\Lambda = 100$
- Free critical parameters $\rho$, $\varepsilon$ and critical target $\chi$ are chosen for the benchmark model as
  - $\varepsilon = -3$ (Allen 2008, and other economic historians)
Benchmark Calibrated Parameters

- $\gamma = -1$ to ensure the elasticity of intertemporal substitution is 2
- Normalizations: $B_{A,1650} = 1$, $\Lambda = 100$
- Free critical parameters $\rho, \varepsilon$ and critical target $\chi$ are chosen for the benchmark model as
  - $\varepsilon = -3$ (Allen 2008, and other economic historians)
  - $\rho = -1$ (complementarity)
Benchmark Calibrated Parameters

- $\gamma = -1$ to ensure the elasticity of intertemporal substitution is 2
- Normalizations: $B_{A,1650} = 1$, $\Lambda = 100$
- Free critical parameters $\rho$, $\varepsilon$ and critical target $\chi$ are chosen for the benchmark model as
  - $\varepsilon = -3$ (Allen 2008, and other economic historians)
  - $\rho = -1$ (complementarity)
  - $\chi = 0.3$
Benchmark Calibrated Parameters

**Table: Calibrated Parameter Values**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_{A,1650}$</td>
<td>$1$</td>
</tr>
<tr>
<td>$b_{A,1650}$</td>
<td>$0.2$</td>
</tr>
<tr>
<td>$c_{A,1650}$</td>
<td>$0.5$</td>
</tr>
<tr>
<td>$B_{M,1600}$</td>
<td>$1.7$</td>
</tr>
<tr>
<td>$v$</td>
<td>$0.25$</td>
</tr>
<tr>
<td>$\bar{a}$</td>
<td>$0.185$</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$0.53$</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$0.82$</td>
</tr>
<tr>
<td>$\rho$</td>
<td>$-1$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>$-1$</td>
</tr>
<tr>
<td>$\delta$</td>
<td>$0.12$</td>
</tr>
<tr>
<td>$\Lambda$</td>
<td>$100$</td>
</tr>
<tr>
<td>$L_{1650}$</td>
<td>$156$</td>
</tr>
<tr>
<td>$M_{1650}$</td>
<td>$0$</td>
</tr>
</tbody>
</table>
Technological Progress Estimation

Need to estimate \{B_{M,t}\} and \{B_{A,t}, b_t, c_t\}.

- Manufacturing Production

\[
B_{M,t} = \left( \frac{r_t}{v} \right)^v \left( \frac{w_t}{1 - v} \right)^{1-v}
\]
Technological Progress Estimation

Need to estimate \( \{ B_{M,t} \} \) and \( \{ B_{A,t}, b_t, c_t \} \).

- **Manufacturing Production**

\[
B_{M,t} = \left( \frac{r_t}{v} \right)^v \left( \frac{w_t}{1 - v} \right)^{1-v}
\]

- **Farm Production**

\[
\frac{b_{A,t}}{c_{A,t}} = \frac{r_t}{w_t} \left( \frac{K_{A,t}}{L_{A,t}} \right)^{1-\varepsilon},
\]

\[
\frac{1 - b_{A,t} - c_{A,t}}{c_{A,t}} = \left( \frac{\Lambda}{L_{A,t}} \right)^{1-\varepsilon} \frac{\rho_{\Lambda t}}{w_t},
\]

\[
B_{A,t} = \frac{w_t}{p_t} \left[ \frac{s_{L,t}^{1-\varepsilon}}{c_{A,t}} \right]^{1/\varepsilon}.
\]
Exogenous Changes: Technology and Trade

a. Estimated Farm and Nonfarm Factor-Neutral Technological Change

b. Factor-Specific Technological Change on the Farm
Exogenous Changes: Technology

a. Estimated Farm and Nonfarm Technical Change

<table>
<thead>
<tr>
<th>Year</th>
<th>Farm TFP</th>
<th>Nonfarm TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1900</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Factor-Specific Technical Change on the Farm

<table>
<thead>
<tr>
<th>Year</th>
<th>Capital-Augmenting Change</th>
<th>Labor-Augmenting Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1650</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1900</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

c. Per Capita Real Import Volume

<table>
<thead>
<tr>
<th>Year</th>
<th>Fraction of 1650 per capita farm output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1650</td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td></td>
</tr>
<tr>
<td>1750</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td></td>
</tr>
<tr>
<td>1900</td>
<td></td>
</tr>
</tbody>
</table>
Exogenous Changes: Population Size

Log of Population Size

Year

log(Population Size)

Oksana Leukhina and Stephen Turnovsky
Population Size Effects in Structural Development
Paris, 2015
Model vs. Data

a. Model vs. Data: Nonfarm Labor / Total

- All effects
- All but farm technology
- All but population
- Data

Year
1650 1700 1750 1800 1850 1900

Nonfarm Labor / Total Labor
0.4 0.5 0.6 0.7 0.8 0.9 1.0
b. Model vs. Data: Nonfarm Labor / Total, 1650-1750

<table>
<thead>
<tr>
<th>Year</th>
<th>Nonfarm Labor / Total Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1650</td>
<td>0.45</td>
</tr>
<tr>
<td>1700</td>
<td>0.5</td>
</tr>
<tr>
<td>1750</td>
<td>0.55</td>
</tr>
<tr>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>1850</td>
<td></td>
</tr>
<tr>
<td>1900</td>
<td></td>
</tr>
</tbody>
</table>

Model vs. Data

Oksana Leukhina and Stephen Turnovsky

Population Size Effects in Structural Development

Paris, 2015
Model vs. Data

c. Model vs. Data: Nonfarm Output / Total

Nonfarm Output / Total Output

Year

1650 1700 1750 1800 1850 1900

0.4 0.5 0.6 0.7 0.8 0.9 1
Model vs. Data

d. Model vs. Data: Real GDP / capita

![Graph showing the comparison of model vs. data for Real GDP per capita over the years from 1650 to 1900.](image-url)
Model vs. Data

e. Model vs. Data: Relative Farm Price

Model vs. Data

f. Investment Rate

Year

Investment rate

1650 1700 1750 1800 1850 1900
### Main Results, Benchmark Model

\( \rho = -1 \)

<table>
<thead>
<tr>
<th></th>
<th>( L_m/L )</th>
<th>( Y_m/Y )</th>
<th>( \log y )</th>
<th>( I/Y )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>% ch. Data, 1650-1920</strong></td>
<td>120</td>
<td>124</td>
<td>26</td>
<td>110</td>
<td>195</td>
</tr>
<tr>
<td>% acct. for by the main experiment</td>
<td>65</td>
<td>62</td>
<td>96</td>
<td>82</td>
<td>102</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>-42</td>
<td>-74</td>
<td>-9</td>
<td>-24</td>
<td>-117</td>
</tr>
<tr>
<td>population effect</td>
<td>56</td>
<td>23</td>
<td>4</td>
<td>45</td>
<td>77</td>
</tr>
<tr>
<td><strong>% of 1650-1750 ch. acct. for by</strong></td>
<td> </td>
<td> </td>
<td> </td>
<td> </td>
<td> </td>
</tr>
<tr>
<td>the main experiment</td>
<td>112</td>
<td>87</td>
<td>95</td>
<td>139</td>
<td>270</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>40</td>
<td>40</td>
<td>74</td>
<td>55</td>
<td>121</td>
</tr>
<tr>
<td>population effect</td>
<td>10</td>
<td>5</td>
<td>-3</td>
<td>37</td>
<td>-8</td>
</tr>
<tr>
<td><strong>% of 1750-1920 ch. acct. for by</strong></td>
<td> </td>
<td> </td>
<td> </td>
<td> </td>
<td> </td>
</tr>
<tr>
<td>main experiment</td>
<td>57</td>
<td>55</td>
<td>97</td>
<td>47</td>
<td>123</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>-80</td>
<td>-155</td>
<td>-24</td>
<td>-186</td>
<td>-55</td>
</tr>
<tr>
<td>population effect</td>
<td>70</td>
<td>32</td>
<td>5</td>
<td>51</td>
<td>69</td>
</tr>
</tbody>
</table>
Main Results, Increase Substitutability

\[(\rho = -0.1)\]

<table>
<thead>
<tr>
<th></th>
<th>(L_m/L)</th>
<th>(Y_m/Y)</th>
<th>(\log y)</th>
<th>(I/Y)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% ch. Data, 1650-1920</td>
<td>120</td>
<td>124</td>
<td>26</td>
<td>110</td>
<td>195</td>
</tr>
<tr>
<td>% acct. for by the main experiment</td>
<td>70</td>
<td>75</td>
<td>97</td>
<td>86</td>
<td>80</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>-36</td>
<td>-55</td>
<td>-10</td>
<td>-28</td>
<td>-128</td>
</tr>
<tr>
<td>population effect</td>
<td>50</td>
<td>27</td>
<td>4</td>
<td>44</td>
<td>72</td>
</tr>
<tr>
<td>% of 1650-1750 ch. acct. for by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the main experiment</td>
<td>95</td>
<td>73</td>
<td>96</td>
<td>140</td>
<td>247</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>25</td>
<td>23</td>
<td>74</td>
<td>52</td>
<td>121</td>
</tr>
<tr>
<td>population effect</td>
<td>14</td>
<td>9</td>
<td>-3</td>
<td>37</td>
<td>-8</td>
</tr>
<tr>
<td>% of 1750-1920 ch. acct. for by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the main experiment</td>
<td>66</td>
<td>81</td>
<td>97</td>
<td>52</td>
<td>96</td>
</tr>
<tr>
<td>farm technology effect</td>
<td>-56</td>
<td>-88</td>
<td>-24</td>
<td>-179</td>
<td>-64</td>
</tr>
<tr>
<td>population effect</td>
<td>58</td>
<td>32</td>
<td>5</td>
<td>46</td>
<td>63</td>
</tr>
</tbody>
</table>

Oksana Leukhina and Stephen Turnovsky ( ) Population Size Effects in Structural Development

Paris, 2015 38 / 40
### Sensitivity: % of Empirical Change Accounted for

<table>
<thead>
<tr>
<th>$\varepsilon$</th>
<th>$\bar{\alpha} / a$</th>
<th>$\rho$</th>
<th>model</th>
<th>1650-1920</th>
<th>1750-1920</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$L_m / L$</td>
<td>$Y_m / Y$</td>
<td>$I / Y$</td>
</tr>
<tr>
<td>-3</td>
<td>0.3</td>
<td>-2</td>
<td>total</td>
<td>63</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pop.</td>
<td>58</td>
<td>21</td>
</tr>
<tr>
<td>-3</td>
<td>0.3</td>
<td>-1</td>
<td>total</td>
<td>65</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pop.</td>
<td>56</td>
<td>23</td>
</tr>
<tr>
<td>-3</td>
<td>0.5</td>
<td>-1</td>
<td>total</td>
<td>68</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pop.</td>
<td>44</td>
<td>14</td>
</tr>
<tr>
<td>-3</td>
<td>0.3</td>
<td>0.5</td>
<td>total</td>
<td>87</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pop.</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td>-1</td>
<td>0.3</td>
<td>-1</td>
<td>total</td>
<td>52</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pop.</td>
<td>41</td>
<td>19</td>
</tr>
</tbody>
</table>
Conclusions

Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:
Conclusions

- Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

- The main mechanism:
  - Low substitutability between factors of production on the farm, with land given in fixed supply
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:
- Low substitutability between factors of production on the farm, with land given in fixed supply
- Absorption of labor in the nonfarm sector – determined by demand conditions substitutability of farm and nonfarm products was greatly facilitated by the expansion of trade

Farm technology is important for the earlier period, 1650-1750
Nonfarm technology drives output dynamics
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:

- Low substitutability between factors of production on the farm, with land given in fixed supply
- Absorption of labor in the nonfarm sector – determined by demand conditions substitutability of farm and nonfarm products
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:

- Low substitutability between factors of production on the farm, with land given in fixed supply
- Absorption of labor in the nonfarm sector – determined by
  1. demand conditions substitutability of farm and nonfarm products
  2. was greatly facilitated by the expansion of trade
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:

- Low substitutability between factors of production on the farm, with land given in fixed supply
- Absorption of labor in the nonfarm sector – determined by
  - demand conditions substitutability of farm and nonfarm products
  - was greatly facilitated by the expansion of trade

Farm technology is important for the earlier period, 1650-1750
Population size effect appears to be quantitatively important in accounting for the structural development of England, especially since 1750.

The main mechanism:

- Low substitutability between factors of production on the farm, with land given in fixed supply
- Absorption of labor in the nonfarm sector – determined by
  1. demand conditions substitutability of farm and nonfarm products
  2. was greatly facilitated by the expansion of trade

- Farm technology is important for the earlier period, 1650-1750
- Nonfarm technology drives output dynamics