THE BREXIT VOTE, PRODUCTIVITY GROWTH AND MACROECONOMIC ADJUSTMENTS IN THE UNITED KINGDOM

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Peterson Institute for International Economics
25 August 2020

The views expressed here are those of the authors, and not necessarily those of the Bank of England.
Examine the adjustments of the UK economy in response to the outcome of the Brexit referendum in June 2016

Interpret these adjustments economically

Can be conceptualized based on rational responses of firms and households to negative news about productivity growth in the tradable sector
CONTRIBUTION OF THIS PAPER

1. Document stylized facts about UK macroeconomic adjustments to referendum
   ▶ Novel quarterly data for tradable and non-tradable sectors → available online!

2. Introduce a two-sector small open economy model featuring tradable and non-tradable production, where sectors can grow at different speeds
   ▶ Estimate the model using the newly constructed data

3. Conduct Brexit simulation experiments in estimated model
   ▶ Productivity news mechanism generates key empirical adjustment patterns

4. Discuss how specific consequences of Brexit are drivers of productivity growth in the UK tradable sector
Suppose agents learn that productivity growth in $T$ sector is weaker in the future

Upon announcement: expansion in $T$ sector and a contraction in $N$ sector

- immediate fall in relative price of $N$ goods
- opportunity to sell $T$ goods at higher price: temporary “sweet spot”
- resources are shifted towards $T$ sector, away from $N$ sector
- sectoral investment falls, labor market remains robust
- the return on domestic bonds falls sharply

Once news materialize: $T$ sector productivity growth declines

- reversal of resource flow towards the non-tradable sector
interpreting the referendum outcome as “one shock”

Our interpretation: Brexit news ≈ productivity growth in $T \downarrow$

Our simulations show that other types of shocks do not generate the empirically observed adjustment patterns

- E.g. persistent interest rate drop only generated by shock to growth rate rather than level

Drivers behind tradable productivity map into specific Brexit consequences

1. Barriers to trade in goods and services
2. Reduced capital flows
3. Lower labor mobility

⇒ “Deglobalization shock” (Gourinchas and Hale, 2017)
RELATD LITERATURE

▶ Effects of Brexit:
  ▶ *Synthetic control approach.* Born et al. (2018)
  ▶ *News and asset prices.* Broadbent (2017a, 2017b) and Davis and Studnicka (2018)

▶ Calibration of models with T&N sectors:

▶ Small open economy models with shocks to growth rate:

▶ News shocks:
  ▶ Beaudry and Portier (2006), Jaimovich and Rebelo (2009), several others
PLANNING FOR THE REMAINDER OF THE TALK

1. Stylized facts
2. Two sector SOE model
3. Data and estimation
4. Main Brexit simulation
5. Robustness exercises and responses to other shocks
6. Discuss drivers of tradable sector productivity growth
7. Conclusion
STYLIZED FACTS
DOWNWARD GROWTH REVISIONS (IMF)
<table>
<thead>
<tr>
<th></th>
<th>2010Q1</th>
<th>2012Q1</th>
<th>2014Q1</th>
<th>2016Q1</th>
<th>2018Q1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradable</td>
<td>12.1</td>
<td>12.2</td>
<td>12.3</td>
<td>12.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Non-tradable</td>
<td>12.3</td>
<td>12.4</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The diagram illustrates the trend in sectoral gross value added from 2010Q1 to 2018Q1, distinguishing between tradable and non-tradable sectors. The data shows a steady increase in value added for both sectors, with a notable jump following the referendum.
REER AND RELATIVE PRICE ACROSS SECTORS

![Graph showing REER and Relative Price across sectors from 2010Q1 to 2018Q1]
EXPORTS AND TRADE BALANCE
AGGREGATE INVESTMENT

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Actual</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010Q1</td>
<td>10.45</td>
<td></td>
</tr>
<tr>
<td>2012Q1</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>2014Q1</td>
<td>10.55</td>
<td></td>
</tr>
<tr>
<td>2016Q1</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>2018Q1</td>
<td>10.65</td>
<td></td>
</tr>
</tbody>
</table>

Referendum
AGGREGATE HOURS
10-YEAR ZERO-COUPON YIELDS
RECAP OF EMPIRICAL FACTS

- UK macroeconomic activity has slowed relative to pre-referendum expectations
- Growth in tradable sector has remained resilient, slowdown non-tradable sector
- The British pound has been subject to a pronounced depreciation
  - With it the relative price of non-tradables
- Exports have been growing robustly
- Weak aggregate investment, little change in aggregate hours
- UK interest rates have declined relative to their world (US) counterpart
THE MODEL
MAIN FEATURES

- Small Open Economy RBC model
- Two sectors: $T$ and $N$
- Each sector $M = \{T, N\}$ grows at its own rate $g_M$
- Labour and capital are sector-specific
- Treat tradable price as numeraire

$\Rightarrow P_{N,t} = P_t \approx \text{real exchange rate}$

- Assets: bond denominated in $T$ units, bond denominated in $N$ units and bond denominated in composite bundle
The production function in sector $M$ is given by

$$Y_{Mt} = a_{Mt} K_{Mt}^{\alpha_M} (X_{Mt} n_{Mt})^{1-\alpha_M},$$

$$\ln a_{Mt} = \varrho^a_M \ln a_{Mt-1} + \varepsilon^a_{Mt}, \quad \text{with} \quad \varepsilon^a_{Mt} \sim \mathcal{N}(0, \varsigma^a_M)$$

The growth rate of sectoral productivity is defined as

$$g_{Mt} = \frac{X_{Mt}}{X_{Mt-1}},$$

$$\ln \left( \frac{g_{Mt}}{\bar{g}_M} \right) = \varrho^g_M \ln \left( \frac{g_{Mt-1}}{\bar{g}_M} \right) + \varepsilon^g_{Mt}, \quad \text{with} \quad \mathcal{N}(0, \varsigma^g_{MT})$$
HOUSEHOLDS

Household’s preferences are specified as in GHH

\[ U_t = \left[ C_t - X_{Tt-1} \omega^{-1} (\theta_T n_{Tt}^\omega + \theta_N n_{Nt}^\omega) \right]^{1-\gamma} / (1 - \gamma), \]

where \( C_t \) is CES aggregator

\[ C_t = \left[ \zeta^{1-\sigma} C_{Tt}^\sigma + (1 - \zeta)^{1-\sigma} \left( \frac{X_{Tt-1}}{X_{Nt-1}} \right)^{\sigma} \right]^{\frac{1}{\sigma}} \]

Budget constraint

\[
\sum_{M=\{T,N\}} P_{Mt} \left[ C_{Mt} + I_{Mt} + \Phi_M(K_{M,t+1}, K_{M,t}) \right] + B_t^* + P_t B_t + P_t Y_{Nt} s_{yt} \\
= \sum_{M=\{T,N\}} \left[ P_{Mt} r_{Mt}^M K_{Mt} + W_{Mt} n_{Mt} \right] + \frac{B_{t+1}^*}{1 + r_t^*} + P_t \frac{B_{t+1}}{1 + r_t}
\]
CLOSING THE ECONOMY

- The interest rate on the $T$-denominated bond is given by

$$r_t^* = \bar{r}^* + \psi \left( e^{B_{t+1}/X_{Tt}} - \bar{b}^* - 1 \right) + \left( e^{\mu_t - 1} - 1 \right)$$

- Results unaffected by the way we close economy (Schmitt-Grohe and Uribe, 2003)

- Market clearing

$$Y_{Tt} = C_{Tt} + I_{Tt} + \frac{\phi_T}{2} \left( \frac{K_{Tt+1}}{K_{Tt}} - \bar{g}_{Tt} \right)^2 + T B_t$$

$$Y_{Nt} = C_{Nt} + I_{Nt} + \frac{s}{y} Y_{Nt} s_t + \frac{\phi_N}{2} \left( \frac{K_{Nt+1}}{K_{Nt}} - \bar{g}_{Nt} \right)^2$$

$$TB_t = B_t^* - \frac{B_{t+1}}{1 + r_t^*}$$
KEY EQUATIONS

- The detrended bond Euler equations

\[
\lambda_t \nu_t = \beta (1 + r_t^*) g_{Tt}^{-\gamma} \mathbb{E}_t \lambda_{t+1} \nu_{t+1}
\]

\[
\lambda_t \nu_t p_t = \beta (1 + r_t) \frac{g_{Tt}^{1-\gamma}}{g_{Nt}} \mathbb{E}_t p_{t+1} \lambda_{t+1} \nu_{t+1}.
\]

- The relative price can be written as

\[
p_t = \frac{c_{T,t}}{c_{N,t}} \frac{1 - \frac{c_{T,t}}{C_t}}{rac{c_{T,t}}{C_t}}
\]

- \( p_t \) is related to MRS between sectors and forward-looking Euler equations

- Shocks to \( g_{T,t+j} \) will affect \( p_t \) today
INTUITION AND ANALYTICAL RESULTS

► Central to our mechanism: movement of relative price and relative returns across the non-tradable and tradable sector

► These movements unfold ...
  ► ... across time: Euler equations
  ► ... across sectors: substitution across goods

► In the paper, we also present a two-period endowment version of the model, in which we show analytically:

\[
\frac{\partial r_N}{\partial g_T^T} > 0 \quad \text{and} \quad \frac{\partial p}{\partial g_T^T} > 0
\]
OUR STRATEGY

- We first estimate the model at business cycle frequencies to pin down starting point of our simulations (parameters and balanced growth path)

- Use novel data on sectoral productivity and the relative price of $N$ output

- Based on estimated parameters, conduct Brexit experiment
  - Feed in news about productivity growth rate in $T$ sector
DATA AND ESTIMATION
DATA AND ESTIMATION

- Construct time-series data for $T$ and $N$ Gross Value Added and labor productivity
  - Classify 2-digit SIC sectors into $T$ and $N$ using supply and use tables for 1997-2016 (Lombardo and Ravenna, 2012)
  - Chain-link detailed industry data using the standard ONS methodology and add up sectoral hours

- This is a novel data set for the UK
  - Same data we use for some of the stylized facts
  - Now available online!
**DATA AND ESTIMATION**

**Table:** Industries shares in non-tradable and tradable sector (\%)

<table>
<thead>
<tr>
<th></th>
<th>Non-tradable</th>
<th>Tradable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0.07</td>
<td>1.35</td>
</tr>
<tr>
<td>Mining and Quarrying</td>
<td>0.00</td>
<td>2.29</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.89</td>
<td>20.99</td>
</tr>
<tr>
<td>Electricity, Gas, Steam Air Conditioning</td>
<td>3.19</td>
<td>0.00</td>
</tr>
<tr>
<td>Water Supply, Sewage, Waste Mgmt</td>
<td>1.07</td>
<td>0.91</td>
</tr>
<tr>
<td>Construction</td>
<td>10.93</td>
<td>0.00</td>
</tr>
<tr>
<td>Services</td>
<td>83.85</td>
<td>74.46</td>
</tr>
</tbody>
</table>
DATA AND ESTIMATION

- The model is estimated with Bayesian techniques

- Use aggregate UK time-series data from 1987Q3 - 2016Q2 (period during which the UK was a full member of the EU)

- This estimation procedure gives us:
  - Values for the structural parameters
  - A balanced growth path from which we can start simulations
OBSERVABLES FOR ESTIMATION

- **New time-series.** Quarterly growth rates of sectoral labor productivity and of the relative price of non-tradable goods

- **Traditional macro variables: shares.** Consumption, investment and trade balance (as nominal shares of GDP)
  - ⇒ sample averages of nominal ratios are correctly pinned down

- **Traditional macro variables: other.** Quarterly growth rate of the real effective exchange rate and total hours

- Not all series available over full sample: handle with Kalman filter
STRUCTURAL SHOCKS

- Sectoral productivity shocks to level and growth rates, risk-premium shock, government spending shock, foreign interest rate shock, exchange rate shock
  - No news shock in the estimation

- Introduce measurement errors for each of the constructed observables

- Also look at alternative shocks and explain how they generate different dynamics
## Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Period</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_T )</td>
<td>ONS &amp; own calcs</td>
<td>1994 – 2016</td>
<td>( n_T/n = 0.5 )</td>
</tr>
<tr>
<td>( \theta_N )</td>
<td>ONS &amp; own calcs</td>
<td>1994 – 2016</td>
<td>( n_N/n = 0.5 )</td>
</tr>
<tr>
<td>( s )</td>
<td>ONS &amp; own calcs</td>
<td>1987 – 2016</td>
<td>( 0.184 )</td>
</tr>
<tr>
<td>( \delta_M )</td>
<td>ONS &amp; own calcs</td>
<td>1987 – 2016</td>
<td>( i/y = 0.181 )</td>
</tr>
<tr>
<td>( \bar{g}_T )</td>
<td>ONS &amp; own calcs</td>
<td>1987 – 2016</td>
<td>( 1.83% )</td>
</tr>
<tr>
<td>( \bar{g}_N )</td>
<td>ONS &amp; own calcs</td>
<td>1987 – 2016</td>
<td>( 1.02% )</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>mid-range estimate</td>
<td></td>
<td>(-0.5)</td>
</tr>
<tr>
<td>( \beta )</td>
<td></td>
<td></td>
<td>( r^* = 0.01 )</td>
</tr>
<tr>
<td>( \psi )</td>
<td></td>
<td></td>
<td>( 5 \times 10^{-6} )</td>
</tr>
<tr>
<td>( \phi_N )</td>
<td></td>
<td></td>
<td>( 4 )</td>
</tr>
<tr>
<td>( \gamma )</td>
<td></td>
<td></td>
<td>( 2 )</td>
</tr>
</tbody>
</table>
## POSTERIOR MEAN ESTIMATES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Distribution</th>
<th>Mean</th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$c_T/C$</td>
<td>Gaussian</td>
<td>0.59</td>
<td>0.57</td>
<td>0.61</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Gaussian</td>
<td>1.99</td>
<td>1.85</td>
<td>2.13</td>
</tr>
<tr>
<td>$\alpha_T$</td>
<td>Gaussian</td>
<td>0.31</td>
<td>0.30</td>
<td>0.32</td>
</tr>
<tr>
<td>$\alpha_N$</td>
<td>Gaussian</td>
<td>0.25</td>
<td>0.24</td>
<td>0.26</td>
</tr>
<tr>
<td>$\phi_T$</td>
<td>Gaussian</td>
<td>9.65</td>
<td>8.45</td>
<td>10.85</td>
</tr>
<tr>
<td><strong>Selected Shocks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varsigma^g_N$</td>
<td>Inv. Gamma</td>
<td>0.014</td>
<td>0.012</td>
<td>0.016</td>
</tr>
<tr>
<td>$\varsigma^g_T$</td>
<td>Inv. Gamma</td>
<td>0.014</td>
<td>0.012</td>
<td>0.016</td>
</tr>
<tr>
<td>$\varsigma^a_T$</td>
<td>Inv. Gamma</td>
<td>0.013</td>
<td>0.011</td>
<td>0.015</td>
</tr>
<tr>
<td>$\varsigma^a_N$</td>
<td>Inv. Gamma</td>
<td>0.013</td>
<td>0.011</td>
<td>0.012</td>
</tr>
<tr>
<td>$\varrho^g_N$</td>
<td>Beta</td>
<td>0.25</td>
<td>0.07</td>
<td>0.43</td>
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<tr>
<td>$\varrho^g_T$</td>
<td>Beta</td>
<td>0.15</td>
<td>0.04</td>
<td>0.25</td>
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<tr>
<td>$\varrho^a_N$</td>
<td>Beta</td>
<td>0.75</td>
<td>0.58</td>
<td>0.93</td>
</tr>
<tr>
<td>$\varrho^a_T$</td>
<td>Beta</td>
<td>0.97</td>
<td>0.95</td>
<td>0.99</td>
</tr>
</tbody>
</table>
BREXIT SIMULATIONS
THE BREXIT EXPERIMENT

- The economy starts on its balanced growth path in period 0

- In period 1, it is revealed that there will be a persistent reduction in tradable sector TFP growth from period 11
  - Mimics period between EU referendum and (unmet) Brexit deadline of March 2019

- Upon arrival of news, households see full future path of productivity growth in $T$
  - *No uncertainty* (“MIT shock”)

- The economy converges in the long-run to the same balanced growth path
Calibrate scale of shock using studies of the potential Brexit effects

<table>
<thead>
<tr>
<th>Study</th>
<th>Estimated reduction in trade, %</th>
<th>Estimated reduction in GDP, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ebell and Warren (2016)</td>
<td>21–29</td>
<td>2.7–3.7</td>
</tr>
<tr>
<td>IMF (2018)</td>
<td></td>
<td>5.2–7.8</td>
</tr>
</tbody>
</table>

We calibrate our experiment so trade falls by 10% (conservative estimate)

Our long-impact on GDP is 3% consistent with 0.3 trade elasticities
In our scenario, the growth rate of LAP in $T$ is determined by:

$$
\ln (g_T) = \varphi_g \ln (g_{T-1}) + (1 - \varphi_g) \ln (\bar{g}_T)
$$

$$
\ln (\bar{g}_T) = \tilde{\varphi}_g \ln (\tilde{g}_{T-1}) + (1 - \tilde{\varphi}_g) \ln (\bar{g}_T) + \varepsilon_{Tt},
$$

where $\tilde{\varphi}_g > \varphi_g$ so that $\bar{g}_T$ represents the persistent component.

We set $\tilde{\varphi}_g = 0.95$ and $\varphi_g = 0.8$.

- Initial fall in $T$ productivity growth is gradual.
- Level of productivity level back on BGP after about 30 years.
EFFECT ON AGGREGATES

A: Tradable sector TFP growth (annualized %)
B: Chain-linked GDP (100*log)
C: Tradable sector output (100*log)
D: Non-tradable sector output (100*log)
E: Trade balance/output (%)
F: Relative price of non-tradable output (100*log)

- Baseline
- Scenario
EFFECT ON INPUT FACTORS AND BOND RATES

A: Hours worked, tradable sector (level)

B: Hours worked (level), non-tradable sector

C: Tradable sector investment (100*log)

D: Non-tradable sector investment (100*log)

E: Tradable bond rate (annualized %)

F: Non-tradable bond rate (annualized %)

Baseline  Scenario
MACRO ADJUSTMENTS IN THE UK

- Model responses in line with the empirical adjustment patterns
  - GDP growth in the UK slows down since the referendum vote
  - The relative price of non-tradables falls permanently
  - Growth rate of the $T$ sector increases relative to the $N$ sector
  - Exports increase after the referendum, creating a *sweet spot*
  - Bond return denominated in terms of $N$ goods falls on impact
  - Sectoral investment falls and labor market remains resilient
ROBUSTNESS EXERCISES AND COMPARISON WITH OTHER STRUCTURAL SHOCKS
LONGER ANTICIPATION PHASE

A: Tradable sector TFP growth (annualized %)

B: Chain-linked GDP (100°log)

C: Tradable sector output (100°log)

D: Non-tradable sector output (100°log)

E: Trade balance/output (%)

F: Relative price of non-tradable output (100°log)

- Baseline
- Scenario
- Fifteen quarter anticipation
LESS PERSISTENCE IN BREXIT SHOCK

A: Tradable sector TFP growth (annualized %)

B: Chain-linked GDP (100*log)

C: Tradable sector output (100*log)

D: Non-tradable sector output (100*log)

E: Trade balance/output (%)

F: Relative price of non-tradable output (100*log)

- Baseline
- Scenario
- Less persistent variant
LEVEL RATHER THAN GROWTH RATE SHOCK IN $T$
LEVEL RATHER THAN GROWTH RATE SHOCK IN $T$
RISE IN PRODUCTIVITY GROWTH IN $N$ RATHER THAN FALL IN $T$
RISE IN PRODUCTIVITY GROWTH IN $N$ RATHER THAN FALL IN $T$
WHY OTHER SHOCKS DO NOT MATCH THE EMPIRICS

- Level rather than growth rate shock in $T$
  - Generates a short-lived interest rate differential exactly when the shock materializes
  - Inconsistent with the persistent decoupling of UK from world interest rates in the data immediately after the referendum

- Rise in productivity growth in $N$ rather than fall in $T$
  - To generate the on-impact reduction in the relative price of non-tradable goods, a (perhaps implausibly) large increase in productivity growth in $N$-sector is required
  - Shock implies a large long-run expansion in GDP as well as a large increase in domestic rate → difficult to find theoretical arguments in support

- A number of other shocks also do not generate the observed adjustment
  - Preference shocks, government spending shocks, risk premium shock, ...
DISCUSSION: DRIVERS OF PRODUCTIVITY GROWTH IN THE TRADABLE SECTOR
Our interpretation: Brexit news $\approx$ productivity growth in $T \downarrow$

Simulations show that this shock generates the empirically observed adjustment patterns, other structural shocks do not.

Final part of the paper: show that economic drivers behind tradable productivity map into specific Brexit consequences that commentators have pointed to:

- Trade barriers, capital flows, labor mobility
- This lends further support to our overall interpretation of the adjustments
1. Barriers to trade in goods and services
   ▶ Classic theories about how trade barriers endogenously determine the rate of growth of an economy, e.g. Grossman and Helpman (1989, 1991)
   ▶ Growth-enhancing resources in the UK's tradable sector may have to be diverted to import substitution after Brexit ⇒ future $g_T \downarrow$

2. Reduced capital flows
   ▶ Less FDI, fewer technological spillovers, see e.g. McGrattan and Waddle (2020)
   ▶ May reduce technology capital investments in tradable activities ⇒ future $g_T \downarrow$

3. Lower labor mobility
   ▶ Portes and Forte (2017): potential restrictions on movement of workers will likely have a significant negative impact on UK growth and productivity ⇒ future $g_T \downarrow$

⇒ “Deglobalization shock” (Gourinchas and Hale, 2017)
CONCLUSION
CONCLUSION

- Document the UK’s macroeconomic adjustments to the 2016 referendum
- Interpret referendum negative news about the tradable sector
- Observed responses are consistent with this theoretical rationalization
- Central to the mechanism:
  - Immediate permanent drop in relative price of nontradables
  - “Sweet spot” for tradable producers
  - Fall in domestic interest rate
  - Resource reallocation during the anticipation phase
  - Reversal upon the realisation of the shock