# Energy efficiency and rebound effects – an example of the 'law of unintended consequences'
# *and other key results from economy-wide research*

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# Introduction

- Focus on use of computable general equilibrium (CGE) models to simulate economy-wide and carbon generation impacts of potential changes in different production and consumption activities
- Scenario analysis (what if)
- Impact of rebound effects of increased efficiency in the use of energy – focus on domestic carbon generation from a production accounting perspective (PAP)
- Integration of CGE analysis with IO carbon accounting tool presented yesterday
- Consideration of implications of taking a consumption accounting perspective (CAP) or carbon footprint approach to examine impacts of an export-led expansion – who is responsible?

# Energy efficiency – a magic bullet?

- Intergovernmental Panel on Climate Change (IPCC) of the UN
- By 2030 energy efficiency gains will provide a substantial part of the remedy for climate change
- Reducing global energy consumption by app. 30% below where it would otherwise be
- Nearly sufficient to offset projected economic growth-driven energy consumption increase

- Stern report states that the “technical potential for efficiency improvements to reduce emissions and costs is substantial”
- Cites IEA finding that the “energy efficiency has the potential to be the biggest source of emissions savings in the energy sector”
- UK Energy White Paper (2003) describes energy efficiency as “the cheapest, cleanest and safest way of addressing our energy policy objectives”.

# On the other hand…

- The European Economic and Social Committee (EESC) suggest that increases in energy demand *despite* energy efficiency policies and measures will be one of the biggest challenges facing EU energy policy.

  (http://www.eesc.europa.eu/?i=portal.en.energy)

- Despite or because of?

- EESC picked up on a debate……rebound effects – response to changing energy prices as a result of energy efficiency improvements may lead to increased energy demand that partially or wholly offsets expected energy savings

- UK House of Lords, Energy efficiency, science and technology committee, 2nd report of session 2005-06
- Could rebound effects offer an explanation for why increases in energy efficiency haven't been accompanied by reductions in energy use at the macro level?

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## System-wide effects of a stimulus to energy efficiency

Example: Would a 5% increase in energy efficiency result in a 5% reduction in the consumption of energy, as some (engineers, environmentalists) have presumed?

The Catch: A technological boost in energy efficiency *reduces* the price of energy in efficiency units, or the price of *energy services*, which tends to *stimulate* the demand for energy. This is the source of rebound

If there is local energy supply, as energy demand falls with increased efficiency, *actual* energy prices will also fall, further stimulating the demand for energy

Seven economy-wide impacts we need to think about, which all help determine the ultimate effect on aggregate energy use and CO2 emissions:

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# Seven general equilibrium effects

1. The technical or **pure efficiency effect**, where we need less energy to produce a given unit of output – **energy demand in targeted sector falls**
2. A **substitution effect**, where energy is substituted for other inputs, as its implicit price (price of energy servies) falls – **energy demand rises**
3. An **output/competitiveness effect** (eg on exports), from this beneficial supply-side shock – **energy demand rises**
4. A **compositional effect**, since different goods vary in their energy intensities ➔ change in structure of output in the economy – **energy demand rises**
5. An **income effect** on households – **energy demand rises**

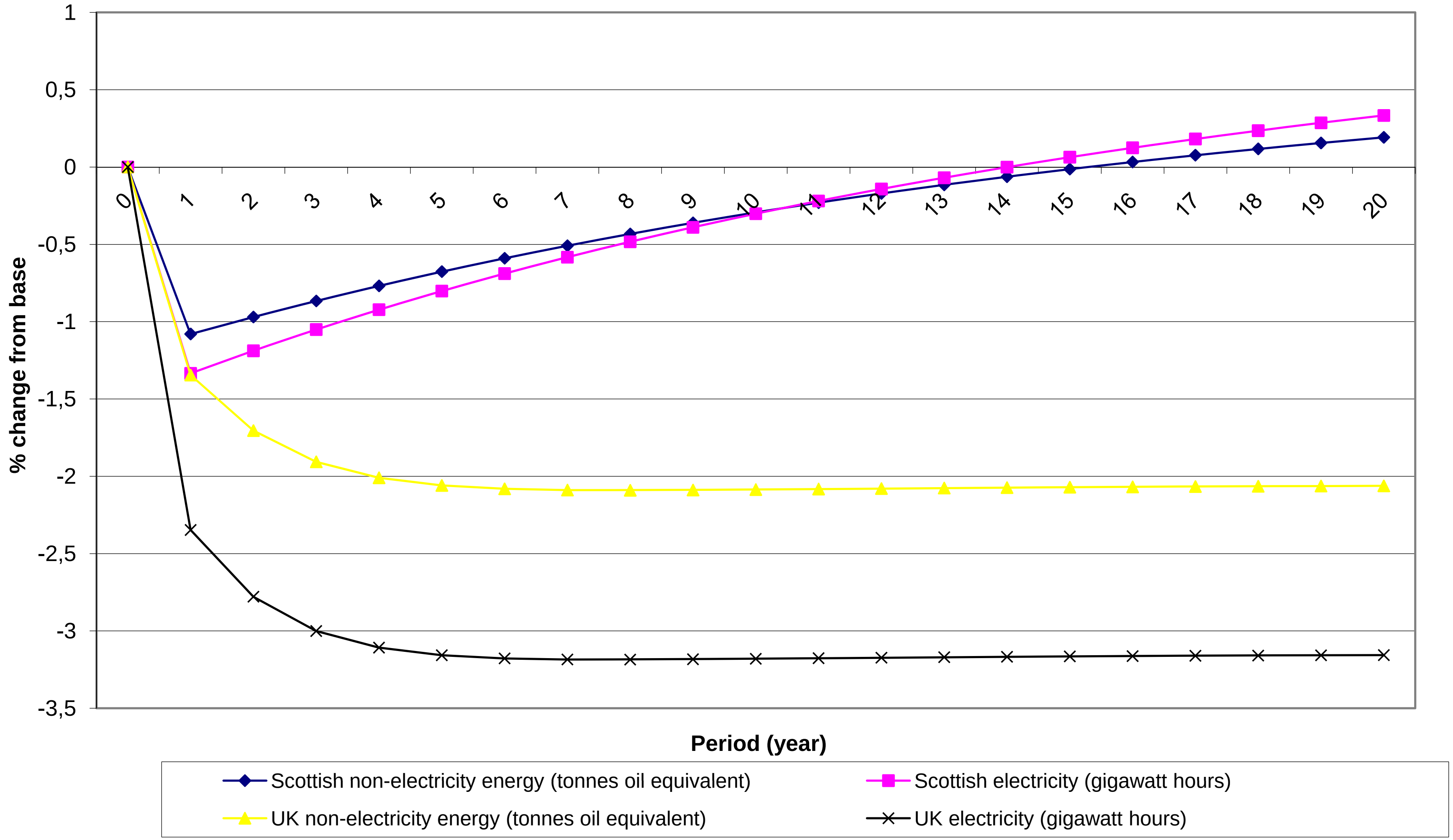
Our research suggests two more, supply-side, effects

6. A **negative multiplier effect** – **energy demand falls**
7. A **disinvestment effect**, whereby falling returns in local energy supply sectors may lead to shedding of capital stock and contraction in the elasticity of local energy supply – **energy demand falls**

# Defining "Rebound" and "Backfire"

- At the system-wide level, the demand for energy (in physical units) from a 5% improvement in energy efficiency could thus:
  - fall by 5% (*zero rebound*)
  - fall by more than 5% (*negative rebound*)
  - fall by less than 5% (*rebound*)
  - remain unchanged (*complete rebound*)
  - increase (*backfire*)
- Changes in energy use map onto changes in pollution
- Need a model that captures the complex network of interactions between different producers and consumers within an economy (also between trading economies?)
- Need to consider *before* we enact energy efficiency improvement programmes

**Figure 1 Percentage change in total energy consumption in Scotland and the UK in response to a 5% improvement in energy efficiency in all production sectors (applied to locally supplied energy)**



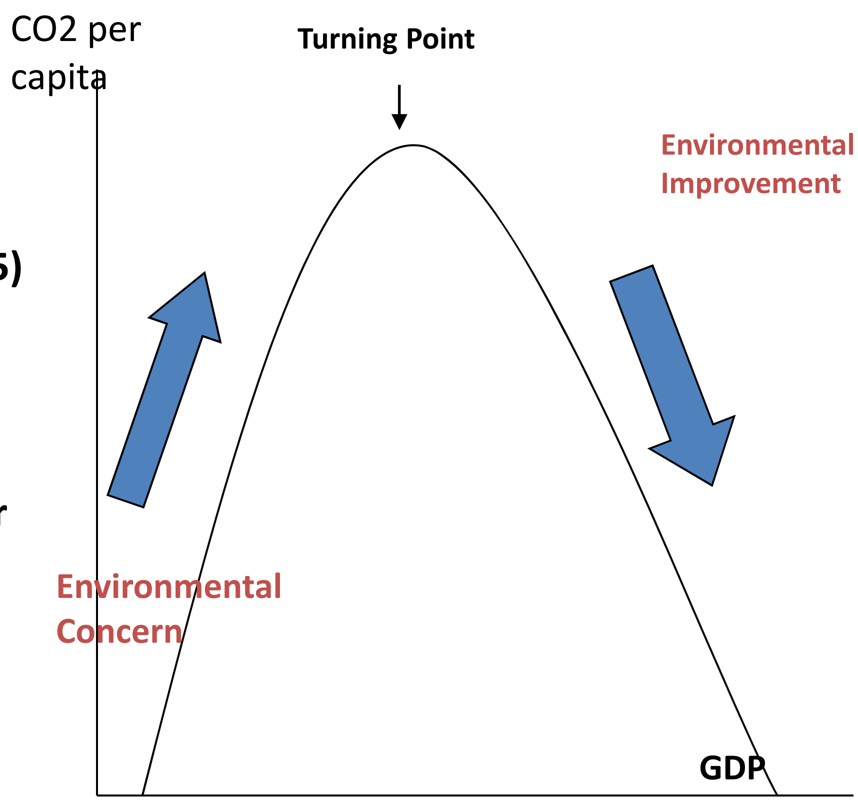
# Economic Growth and the Environmental Kuznets Curve

**Main theoretical arguments**

1. **Structural change (Jaffe, 2003)**
2. **Willingness to pay (Hokby and Soderquist, 2003)**
3. **Technological change (Bretschger, 2005)**

**Our focus is on technological change**

- **Factor efficiency improvements**
- **See Johansson and Kristrom (2007) for SO2 in Swedish case**

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## Policy implication if true:

- Policymakers making decisions have to consider economic and environmental concerns
- EKC – a hypothesis how may interact, but implies
- We can grow without worrying about continually-increasing pollution
- Less of a trade-off between economic growth and environmental sustainability (with own economy at least!)
- Countries can “grow their way” out of environmental problems
- But rebound (particularly backfire)  is one factor that may cause EKC to break down

# Impact of excluding Scottish energy supply from efficiency improvement

Backfire effects (rebound >100%) driven by positive competitiveness effects in heavily traded and highly energy intensive Scottish energy supply sectors

- Limit energy efficiency improvement to energy use sectors, only get backfire when elasticity of substitution in favour of energy is highly price response, or elastic (>1)
- Otherwise, move past turning point of EKC, with decrease in absolute CO2

**Table 3. Impacts of a 5% increase in energy efficiency limited to the 20 non-energy supply Scottish production sectors**
**Flexible real wage/flexible population**
**% change from base year values**

| | Base Year Values | Key KLEM elasticities of substitution | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.4 | | 0.8 | | 1.1 | |
| | | SR | LR | SR | LR | SR | LR |
| Total electricity consumption (tonnes oil equiv) | 32,038 | -1.04 | -0.97 | -0.23 | -0.02 | 0.42 | 0.70 |
| Total non-electricity energy consumption (tonnes oil equiv) | 17,998,420 | -0.72 | -0.66 | -0.18 | -0.02 | 0.25 | 0.47 |
| Total CO2 generation (tonnes) | 48,509,902 | -0.69 | -0.66 | -0.18 | -0.02 | 0.25 | 0.47 |
| CO2 Intensity of GDP (CO2/GDP) (tonnes per £1m) | 775 | -0.73 | -0.95 | -0.22 | -0.28 | 0.22 | 0.23 |
| EKC per capita (tonnes indexed to UK pop=1) | 13 | **-0.73** | **-1.24** | **-0.22** | **-0.53** | 0.22 | 0.01 |

# Energy efficiency improvements in production vs consumption

- Generally, energy efficiency improvements in production will act to improve economic productivity and performance – in absence of backfire, will be accompanied by a net reduction in energy use (and related pollution generation)….just not as large as may have been anticipated
  - Need to adjust energy efficiency targets to compensate for rebound?

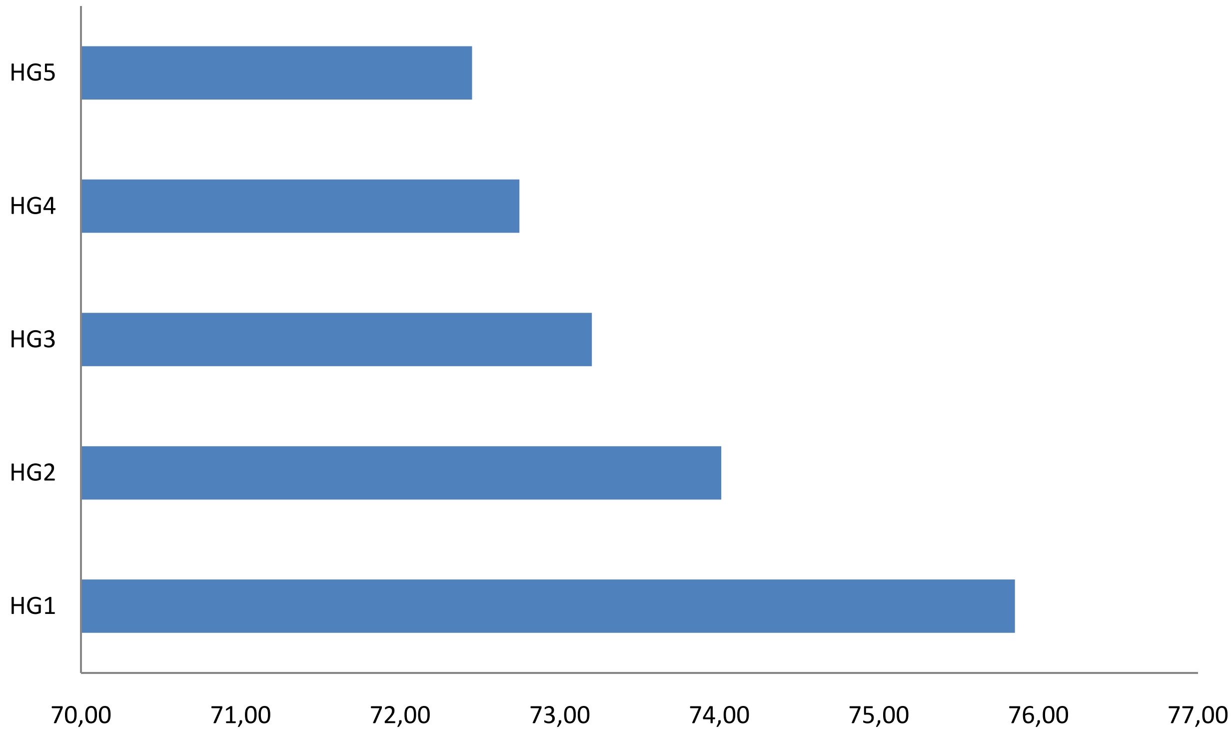
- Not such a clear 'double dividend' in the case of energy efficiency improvements in household consumption (so EKC hypothesis may not be relevant at this level)

- Previous research, focussing mainly on rebound effect within households (micro level), rather than economy-wide, hasn't highlighted this key issue

- Increases in efficiency transmit to production side of the economy in form of a demand shock – even with rebound, shift away from energy in favour of non-energy goods

- Our research, net boost to economic activity (GDP, employment, household consumption) but with reduced competitiveness and contraction in local energy supply (disinvestment effect)….but net reduction in pollution generation

# Long-run Household rebound effect




| | HG1 | HG2 | HG3 | HG4 | HG5 |
|---|---|---|---|---|---|
| Long run household rebound | 75,85 | 74,01 | 73,20 | 72,75 | 72,45 |

## Conclusions and direction for continued/future research (1)

- General model specification issues – macroeconomic closures, labour market behaviour
- Importance of some key elements of specification for energy modelling, particularly with respect to substitutability of energy for other inputs (and energy for non-energy consumption goods in case of household energy efficiency improvements)
- Issues such as habit formation and potential inertia, e.g. in household energy use
- Importance of the role of capital – as a substitute/complement for energy, as a potential barrier to energy efficiency uptake
- For regional economies in particular (but more generally), understanding migration and other labour market behaviour
- Understanding how/if local energy supply/distribution prices may differ from world/external prices
- Impacts of increased energy efficiency, and other forms of technological progress, at the regional level on pollution generation from consumption and production accoutning perspectives

## Conclusions and direction for continued/future research (2)

- Impacts of increased energy efficiency, and other forms of technological progress, at the regional level on pollution generation from consumption and production accounting perspectives
- Attention not limited to energy efficiency – more generally to consider complex interactions within the economy, structural change etc in designing energy and pollution problem
- Our research more generally - modelling impacts on key indicators of a wide range of disturbances within an economy-wide model
- That is, impacts of changes in economic activity and/or policy on a range of indicators, including, e.g. carbon footprint
- Energy efficiency example above – focus on $CO_2$ generation from a production accounting perspective (PAP) not consumption accounting perspective (CAP)
- But model results could be used to recreate post shock results for IO tool
- Key is not just monitoring indicators, but understanding transmission mechanism through which changes in activity in any given part of the economy impact on production, consumption and pollution generation, and tracking this over time
- Understanding pollution problems from a range of perspectives, taking into account issues of jurisdiction but also complex nature of 'responsibility' issue

# An example to close

- The Welsh regional economy
- Work using input-output accounting methods suggests that the Welsh carbon footprint may be lower than actual carbon generation within the economy
- Issue – high carbon content of exports
- Subtract in a carbon footprint calculation, but add pollution content of imports
- Implication: Wales is not responsible for carbon generated in export production?
- But, consider a current scenario – investment to boost capacity and production to meet export demand in the carbon-intensive 'Iron and Steel' sector
- This would be expected to boost CO2 generation within Wales
- But also GDP and consumption levels
- Will be reflected in footprint, but only indirectly
- Welsh consumers *benefit* (in economic terms at least) from export production

**Table 1. Long-run impacts of a £90million direct boost to export demand for Welsh 'Iron and Steel'**

| | PRE-SHOCK (2003 IO ACCOUNTS) | | POST-SHOCK (LONG-RUN) | | % CHANGE (LONG RUN) | |
|---|---|---|---|---|---|---|
| | PAP | CAP (DTA) | PAP | CAP (DTA) | PAP | CAP (DTA) |
| **Total CO2 (as carbon) attributed (tonnes)** | **11,746,484** | **11,463,605** | **11,843,788** | **11,484,520** | **0.83%** | **0.18%** |
| **CO2 (as carbon) supported by Welsh final demands** | | | | | | |
| **Domestic (Welsh) CO2 (as carbon) generation:** | | | | | | |
| Directly generated (households): | 2,130,600 | 2,130,600 | 2,135,160 | 2,135,160 | **0.21%** | **0.21%** |
| Indirect - generated in Welsh production sectors supported by: | | | | | | |
| Households | 1,397,716 | 1,397,716 | 1,400,770 | 1,400,770 | **0.22%** | **0.22%** |
| Government | 551,445 | 551,445 | 551,470 | 551,470 | **0.00%** | **0.00%** |
| | **4,079,761** | **4,079,761** | **4,087,400** | **4,087,400** | **0.19%** | **0.19%** |
| **Indirect Carbon embodied in imports (hypothetical)** | | | | | | |
| **RUK** | | | | | | |
| Households | | 2,433,967 | | 2,439,382 | | **0.22%** |
| Government | | 568,028 | | 568,092 | | **0.01%** |
| | | **3,001,995** | | **3,007,474** | | **0.18%** |
| **ROW** | | | | | | |
| Households | | 3,431,935 | | 3,439,633 | | **0.22%** |
| Government | | 949,913 | | 950,013 | | **0.01%** |
| | | **4,381,848** | | **4,389,646** | | **0.18%** |
| **Total carbon embodied in imports** | | **7,383,843** | | **7,397,120** | | **0.18%** |
| **CO2 (as carbon) supported by external demands for Welsh production** | | | | | | |
| Exports of goods and services RUK | 5,515,332 | | 5,574,002 | | **1.06%** | |
| Exports of goods and services ROW | 2,059,868 | | 2,090,786 | | **1.50%** | |
| External tourists | 91,523 | | 91,600 | | **0.08%** | |
| **Total carbon embodied in exports** | **7,666,723** | | **7,756,388** | | **1.17%** | |
| **Implied CO2 (as carbon) Trade Balance (Surplus):** | | | | | | |
| Actual CO2 (as carbon) generation minus DTA CO2 (as carbon) generation | | | | | | |
| (CO2 (as carbon) embodied in exports minus CO2 (as carbon) embodied in imports) | | | | | | |
| RUK | | 2,513,337 | | 2,566,528 | | **2.12%** |
| ROW | | (2,321,980) | | (2,298,860) | | **-1.00%** |
| Total (including external tourists) | | 282,879 | | 359,268 | | **27.00%** |

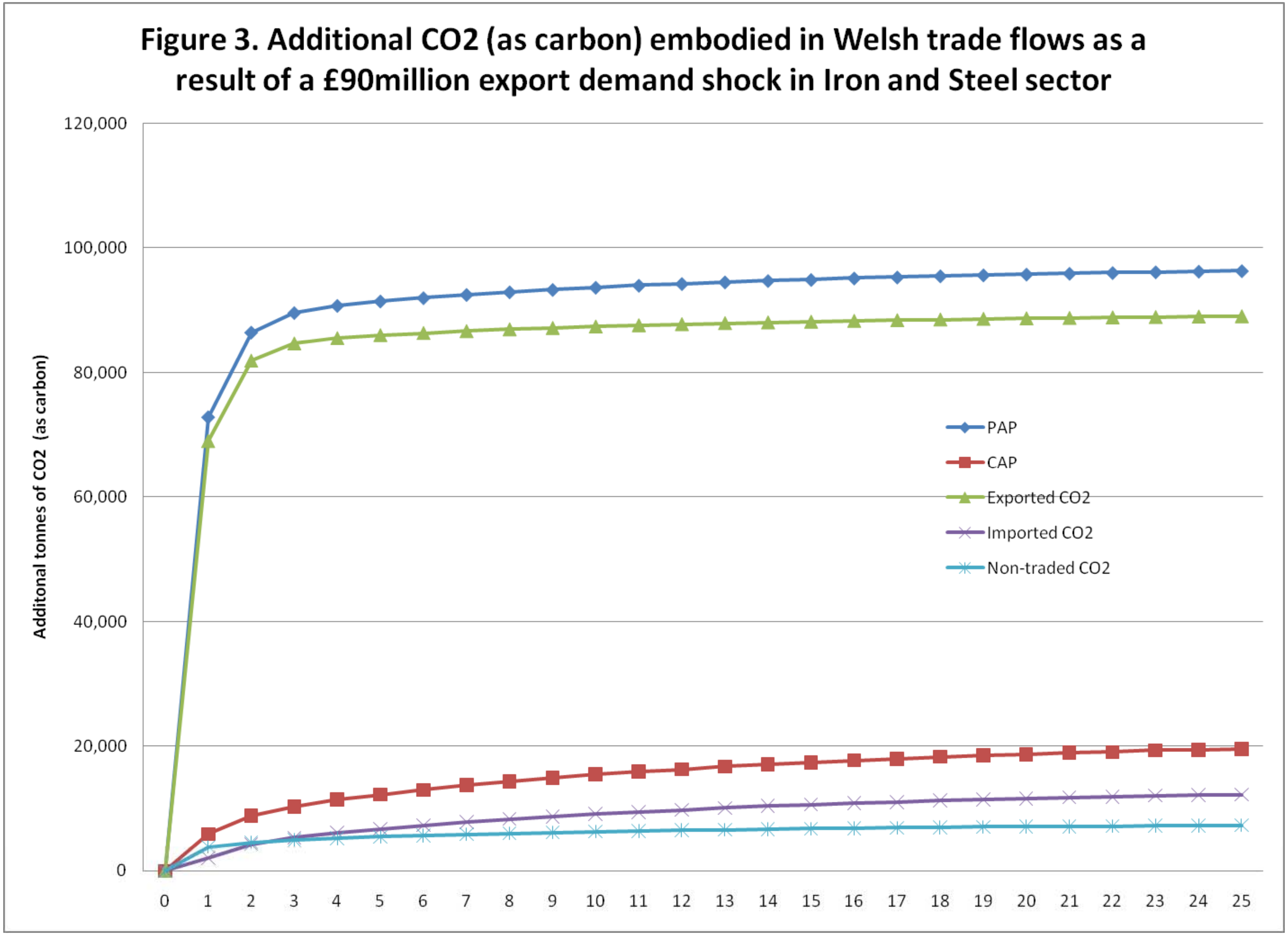


Figure 3. Additional CO2 (as carbon) embodied in Welsh trade flows as a result of a £90million export demand shock in Iron and Steel sector
Additonal tonnes of CO2 (as carbon)
120,000
100,000
80,000
60,000
40,000
20,000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
PAP
CAP
Exported CO2
Imported CO2
Non-traded CO2

- Thank you for listening

- Questions?