in grasslands, which have some of the highest rates of carbon fixation on Earth, suggesting that they might have an even more important role in the carbon cycle than ericoid and ectomycorrhizal fungi.

Orwin and colleagues' study[3] potentially has important implications for modelling the balance of carbon between the biosphere and the atmosphere. Global climate models are the most powerful tools we have at our disposal for predicting the impact of a changing carbon cycle on ecosystems and human societies. It is imperative that these models are both accurate and as precise as possible, as they influence the actions we take to mitigate climate change. The team's results indicate that modifying climate models by incorporating the diverse functions of different microbial groups into their coding could have significant consequences for simulations of the soil-carbon balance, and thus potentially for predictions of future atmospheric carbon dioxide concentrations.

We are not yet, however, at a stage where it is clear that such modifications would improve model predictions of the global carbon balance: more work is needed to understand and quantify the effects that microbial functions — including organic nutrient uptake — have on carbon cycling. An important first step will be to test how different groups of microbes and their activities contribute to carbon cycling in the field, in a way that can be used to validate Orwin and colleagues' model at a regional scale. ❐

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POLICY

Trade's growing footprint

The production of traded goods accounts for a significant proportion of global greenhouse-gas emissions. Now analysis reveals that emissions embodied in imports from developing countries have out-stripped emission reductions made by developed countries at home over the past 20 years.

Carolyn Fischer

The question of the burden that different countries should bear in reducing greenhouse-gas emissions is at the heart of international negotiations to tackle climate change. The 1992 *United Nations Framework Convention on Climate Change* established the principle of 'common but differentiated responsibilities', acknowledging that developed countries bear more responsibility than developing countries for historical emissions, and that emissions from developing countries will need to grow to facilitate their development. Shortly after the convention was adopted, the World Trade Organization was established, enshrining rules and obligations for liberalized trade. Since then, global trade has expanded and shifted, with emerging economies becoming major exporters of manufactured goods, rather than just raw materials and agricultural commodities[1]. Writing in *Proceedings of the National Academy of Sciences*, Peters and colleagues[2] show that these changes make it even more difficult to answer the question of who should be responsible for reducing greenhouse-gas emissions — not least because emissions embodied in imports from developing countries over the past 20 years exceed the emission reductions that developed countries have made within their own territories.

Under the 1997 Kyoto Protocol, developed countries agreed to legally binding emission-reduction targets for 2012. These commitments apply only to greenhouse-gas emissions produced within each country's own territories. By this 'territorial' accounting system, developed countries have stabilized their carbon dioxide emissions since 1990, while emissions from developing countries have doubled[2]. However, this system does not account for the flows of trade between countries and thus overlooks the fact that developed countries are net importers of emissions, while emerging economies are net exporters[3,4].

Peters and colleagues[2] identify important trends in the role that international trade has played in emissions growth at global, regional and country scales. Using a time series of global trade data, they calculated net emission transfers between almost 100 different countries — that is, the emissions generated in a country to produce exported goods and services minus the emissions that are generated elsewhere to produce the goods and services that it imports. Adjusting each country's territorial emissions by this amount, they created inventories that reflect the emissions associated with consumption in each country (Fig. 1).

The analysis shows that net emission transfers from developing to developed countries have been growing steadily, at an average rate of 17% per year. Furthermore, for developed countries as a whole, these transfers exceed the reductions in territorial emissions achieved since 1990. Overall, growth in emission transfers to developed countries through international trade equates to 14% of the growth in global carbon dioxide emissions since 1990. China has played a striking role in these trends: emissions associated with imports from China accounted for 75% of the growth in developed countries' consumption-based emissions. Moreover, Chinese emissions accounted for 55% of the growth in global carbon dioxide emissions from 1990 to 2008, with one-third of this contribution due to exports.

Analysis by sector reveals that energy-intensive industries such as cement and steel production, which are often targeted in climate policies, are not the main source of 'carbon leakage' from developed to developing countries. Trade in these sectors has grown in

both directions since 1990, leaving net emission transfers greater in non-energy-intensive industries, such as manufacture of equipment and electronics. Nor are developed countries' climate policies likely to explain much of the growth in carbon leakage over the past two decades, because they began in earnest only recently. Rather, Peters *et al.*[2] have identified more general trends in emission transfers that are probably driven by a range of socio-economic factors.

The methods used by Peters *et al.*[2] are well-established. However, one caveat to their analysis is that it relies on data that are aggregated by region and by sector. The school of thought known as 'new trade theory' indicates that firms that export goods tend to be more productive than those that produce goods only for domestic consumption[5]. If exporters are indeed less energy intensive than average for a given sector, calculations based on aggregated data will over-estimate emission transfers.

Peters *et al.* downplay the policy implications of their work, but other authors have called for emission transfers to be accounted for in the distribution of post-Kyoto abatement burdens[3]. However, asking developed countries to achieve deeper reductions in their territorial emissions while emissions from emerging economies remain largely unconstrained risks exacerbating the problem of carbon leakage, which would undermine domestic support for stringent regulation of emissions. Developed countries will also resist being made to take responsibility for emissions they cannot control.

Ensuring that consumers in developed countries bear the full cost of the goods they consume, including imported emissions, would require implementation of border carbon adjustments — compliance payments levied on goods imported from countries that do not account for the cost of carbon by countries that do. In theory, careful implementation of border adjustments could reduce carbon leakage and improve the cost-effectiveness of sub-global carbon-pricing programmes[6,7]. Yet such proposals may not be compatible with trade-law obligations[6]. They also raise vehement objections from emerging economies, owing to the anticipated effect on their prospects for growth (which may already be limited by emission constraints imposed on their trading partners)[7].

Recent analysis indicates that implementing regulations or agreements to reduce emissions across specific sectors in developing countries could achieve emission reductions at a much lower cost than trade measures[8]. Thus, it seems that the aim of reducing global emissions would be better served by pursuing common policies in key traded sectors while using other means — such as transferring emission-reduction technologies and financial aid — to differentiate the economic burden among countries.

The crux of the problem explored by Peters *et al.*[2] is that emissions embodied in international trade have grown significantly over the past 20 years, arguably driven by market forces unrelated to climate policy. The trade that these emissions reflect has been a tremendous engine for economic development that has benefited developing and developed countries alike — but the negative consequences that embodied emissions bring will also be borne by both parties. Agreeing on ways to reduce these emissions will be difficult — but the real challenge will be taking responsibility, not assigning it. ❐

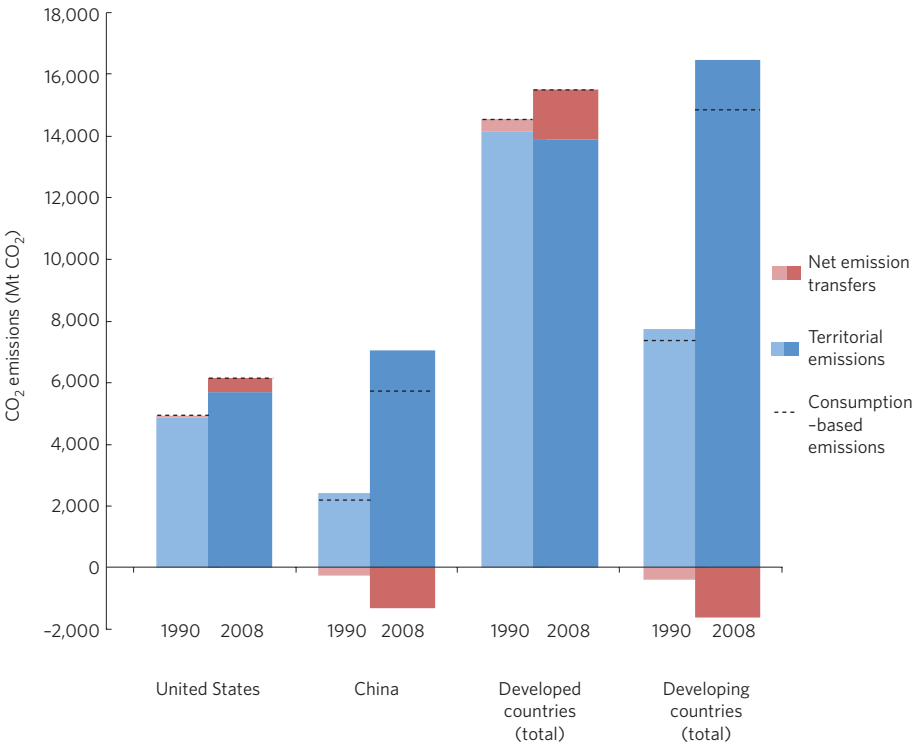

Figure 1 | Emissions embodied in international trade. The chart shows territorial emissions (blue bars), net emission transfers from international trade (red bars), and consumption-based emissions (dotted lines) in 1990 and 2008 for developed and developing countries and the two largest single emitters, the United States and China, calculated by Peters and colleagues[2]. Negative values for emission transfers indicate net export of emissions, whereas positive values reflect net import. Consumption-based emissions are the balance between territorial emissions and net transfers. Although China is the largest emitter on a production basis as of 2008, on a consumption basis the United States remains ahead. Similarly, emissions from developed countries exceed those from developing countries on a consumption basis.

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