

Pigou and the Climate Crisis – internalizing External Effects is no Panacea

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Abstract

The paper analyses whether Pigou's theory of external effects and the concomitant remedy by "internalisation of external effects" is suitable to solve the Climate Crisis considered the biggest market failure ever seen, as Nicholas Stern wrote. Pigou noticed microeconomic market failures if private and social costs diverge. Optimal taxes can solve the problem by getting the prices right. Market failures of this kind can be solved in an enlightened market economy without state failures. Contrasting Pigou, the paper focusses at macroeconomic effects of such market failures and the chances to heal them with Pigouvian taxes of different types, including cap-and-trade systems. However, the Climate Crisis stands out as a very special type of negative externality which does not fit in Pigou's framework. It is argued here that relying on grand scale carbon taxes as the chief or even only policy instrument will likely have limited success and could even cause grave additional problems. The paper pleads for a broad and complex policy mix that goes beyond Pigou but includes carbon taxes. Promotion of positive externalities by means of industrial policy would be part of the policy mix.

1. From Pigou to the Climate Crisis – setting the stage

Arthur Cecil Pigou's theory of externalities and their remedies via internalization of external costs became standard textbook knowledge of environmental economics, hence also applied to the crisis of global warming. The latter is considered the greatest market failure ever seen (Stern 2006). Many economists and politicians hold it requires grand-scale internalization of environmental costs through Pigouvian taxes or similar tools as the main instrument for climate policy (SVR 2019). However, there are doubts whether the climate externality fits into Pigou's analytical framework and to the standard remedy. Pigou's paradigm of market failures may not match the peculiarities of global warming. The paradigm includes the cap-and-trade tools which frame and eventually steer the carbon price by setting limits for the quantity of emission permits. If the carbon price were the only instrument for climate policy, a recent analysis of the Potsdam Institute for Climate Research (Pietzker et al. 2021) found that the carbon price would have to be on average € 275 per ton CO₂ in the European Union in a range of € 210 to 405 in different sectors (see also World Bank 2024).

Since the market supply and demand seemingly govern the price, cap-and-trade systems are considered market-oriented or market-friendly, although one side of the market, namely the

supply, is quantitatively set by the state similar to central planning. The carbon price is then seen as a special offspring of a variable Pigouvian tax. This post-Pigou instrument is more effective and efficient as a traditional Pigouvian tax, but remains within the same paradigm. Neither the old nor the new instrument may suffice to solve the problem of global warming according to the view expressed here. Although necessary, getting the prices right is not the silver bullet for the climate problem. This is the main proposition in this paper.

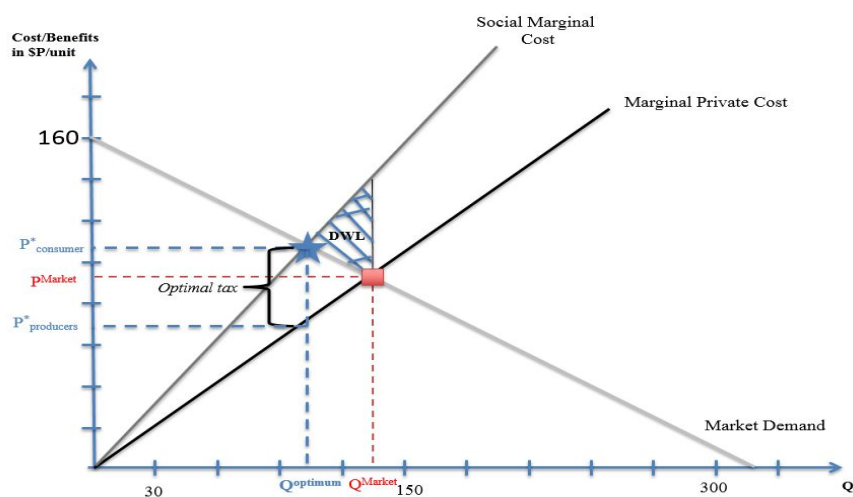
In what follows, I firstly discuss the macroeconomic effects of externalities. If Pigouvian taxes occur in grand scale they do have macroeconomic effects on output, employment, price stability, trade etc. I discuss first the case for static reallocation, then the case for dynamic reallocation. Secondly, I compare the climate issue with the typical negative external effects Pigou had in mind; the paradigmatic misfit will be explained. The internalization approach, hence getting the prices right, is a too narrow approach to the climate problem. The last part concludes.

2. The macroeconomics of externalities

2.1 Static reallocation with Pigouvian taxes

The sum of the costs of negative externalities in an economy is part of the *social costs*, comprising the private or direct costs accruing to the firms and the external costs depending on the size of emissions and on output. In Pigou's welfare economics, the welfare optimum is reached when the marginal social costs equal the marginal output, whereas the marginal private costs intersection with marginal demand (benefits) would yield a higher output, as shown in graph 1 which depicts the standard microeconomic case of a Pigouvian tax as demonstrated in all textbooks. Now, think of a closed economy with only one commodity. The micro result of a Pigouvian tax represents then also the macroeconomic optimum, but output has shrunk if emissions and output move in tandem, hence excluding technical change in the relationship of output to emissions. The initial overproduction is reduced, but the welfare has increased (Pareto-Optimum) marginally. The tax is a steering tax, not geared for revenue increase. After the adjustment, the extra revenue from the tax has shrunk to zero. Either, pollution is reduced by lower output, though not completely, or the firms paid a compensation to the damaged party. The firm sector in the aggregate is not happy, but their discomfort is matched by the relief of the beneficiaries who suffer less pollution. If environmental technical progress is excluded, we have a one-time degrowth with an increase of unemployment under constant working hours per worker. Hence, the pollution is not completely prevented, but reduced to an acceptable amount. Information on the marginal costs curve is assumed.

Graph 1



The macro view on externalities reveals more problems. If negative externalities exist, they incentivise polluters. The latter search for such externalities as a form of rent seeking as long as they can dodge the tax or as long as the state is passive or unable to impose a tax, perhaps due to missing information about the cost curve. If the number of externalities increases and the government is faced with transaction costs when detecting cost curves of the polluters to fix an optimal tax, it looks like an impossible task. In a world with monopolistic competition or monopoly power opportunities to find and *exploit negative externalities* could mushroom, let alone a global open economy with some 200 different jurisdictions on our planet. Relying on Coase's proposal to let polluters negotiate with their damaged counterparts increases the burden of transaction costs even more since the number of this group is a multiple of the number of states on the globe. If negative externalities are ubiquitous, all prices are affected due to input-output interlinkages. *No price tells the truth*. If governments cannot tolerate this, they will have to resort to other tools, such as direct controls, prohibitions, taxes and fees unadjusted to cost curves, import restrictions, technical standards and other tools often described as command-and-control policy. These instruments often do work, they can be effective, but cause costs of bureaucracy and lead to cost inefficiency. Most instruments to avoid damages to people and nature occur in the field of environmental policy, in land use and construction, in the health sector, to name the most important. In reality, Pigou looks like a naïve idealist, half-blind in the real world, although well-meaning to an extent that amounts close to ideology – free markets can function well with a prudent state capable to impose the proper tax. Be the state blamed but not free markets although the state is thrown into mission impossible.

Assuming many negative externalities so that many Pigouvian taxes have to be levied, the macroeconomics of Pigou's ideas must pay more attention to *revenues* from the taxes, especially if the transition pathway is long and gradual so that taxes have to be paid for a longer period. Although the tax is designed as a steering tax it – unintentionally – harvests large amounts of revenues. The micro view doesn't care for the revenue (so did Pigou), the macro view must care. Hence, the revenue can be used to reinforce the goals of internalisation, for

instance for innovation and technological change or for alleviation of hardships of people in need.

How about *tax evasion* in the case of Pigouvian taxes? It may occur with paying taxes combined with pass-through to customers of polluters. A consequence is that relative prices would change less than in the case without evasion. The rationale of the Pigouvian tax is then limited to special cases with high elasticity of substitution or of price elasticity for final consumers. There is some similarity to exchange rate adjustments: their impact on exports and imports depends on elasticities and the degree of non-price competition on international markets. The power of relative international price changes is – especially for advanced countries with strongly diversified tradeable goods – quite limited. Similar happens in case of monopolist or oligopolist competition: changes of output prevail over price changes.

Assume a negative externality is countered by a tax imposed on the production of an entire sector comprising many firms and also many products rather than only one as discussed above. The latter will try to *pass-through the tax to their customers*, eventually the final consumers are taxed who cannot directly lower the damage. They can only purchase less products or other products with less pollution or cheaper untaxed imported goods. Relative prices change, but their environmental effectiveness depends on the behaviour of consumers and the availability of alternative products at lower prices. Pigou's polluters-pay-principle is watered down or fully relinquished. Consumers are seen then as the fellow-polluters. We have externalities of production and of consumption, as observed already by Pigou. If the products whose production is taxed is a key input for other sectors, input-output linkages make tax-evasion via pass-through pervasive, the lower the elasticity of substitution is. It could also happen that firms faced with increasing CO₂-prices in one country may lose price competitiveness on international markets with competitors from countries without CO₂-taxes (Breitschopf et al. 2024).

Compare the pass-through of CO₂-taxes, say in a closed economy, with a hypothetical tax on fixed capital to lower the capital intensity of production and to promote employment. The tax will be passed through and is eventually passed on to final consumers which reduces real wages or stimulates inflation. Capital intensity will remain unaffected. This comparison with a Pigouvian tax might be extreme, but it shows that a macroeconomic analysis with input-output-linkages and the possibility of pass-through is important to assess the effectiveness of the tax. Taxing fossil energy may be similar to taxing capital. If substitutes for fossil energy exist which are cheaper, the case for effective taxes is more favourable. However, if the energy mix during the transition phase of decarbonisation requires a mix of renewables and fossil energies, the effectiveness of the tax is lowered.

There is another downside of the theory of externalities from a macro view. If firms are strongly interested in detecting opportunities for negative external effects, they tend to avoid and suppress *positive external effects* but like to exploit them when unintendedly initiated by competitors or the government. Certainly, positive externalities caused by firms are costly for them like leakages in their vaults. Yet, in many cases positive externalities generated by firms or the government can spill-over to other firms, sectors and nations which in turn may in the end also benefit from the initiators. Think of patent laws that benefit developing countries,

internal training of employees who may move to other employers sooner or later. The causers of positive externalities can also internalize the effects of other causers. Furthermore, research and development and promotion of innovations are candidates for Pigouvian subsidies.

Large scale Pigouvian taxes – or the equivalent in cap-and-trade systems - could potentially be *inflationary*. Assume the tax on mass harmful substances should start with low rates with pre-announced medium- or long-term regular increases, and assume the response of polluters is inelastic. Then the steering function is limited, but in the long run not negligible which implies that prices rise and polluters will pay. Due to input-output interlinkages all prices tend to spiral up. The ensuing inflation may be some kind of green inflation, but it is inflation, not value-added. If the revenues are fully or partially returned to the citizenry and the rest spent by the government, then it is likely that the inflation is reinforced by aggregate demand.

In an *open economy*, eco-taxes, levied only in the country under consideration here, will raise prices of exports and lower the relative price of imports. Price competitiveness of domestic industries suffers (Breitschopf et al. 2024) . If the tax is effective, green products will be less exported and more brown ones are imported. Furthermore, capital might move to abroad where costs are lower. Little progress is achieved unless the global demand for green but more expensive goods rises. Hence, a *border adjustment mechanism*, like a tax or fee on brown imports, could be levied (Kolev et al. 2021). Free trade is undermined. This may be a sensible measure, but it generates massive problems for the world economy and could fire trade wars.

2.2. Dynamic reallocation with Pigouvian taxes

So far, we dealt mainly with static allocation. How about dynamic allocation? Following the graph, output as well as welfare-neutral growth is only possible if growth and environmental technical progress (etp) move in lockstep so that the quantity of pollution remains unchanged. Otherwise, the Pigouvian tax has to increase continuously until both pollution and output reach zero. If this is unwanted, behavioural change – to prevent or to adjust to environmental harms – could replace etp. For continuous growth of output, continuous behavioural change would be necessary. This is as unlikely as is a continuous tax increase up to zero emissions. In case the external costs or the pollution are so high that all emissions have to be avoided, we would need *prohibitive Pigouvian taxes* which amount to an outright prohibition of this production. In other words, in the centre of the adjustment should be environmentally friendly technical change, and the Pigouvian tax makes only sense if it triggers this change or invokes changes in consumption behaviour. In a purely microeconomic analysis, the polluting firm would have more adjustment options in case of an imposed Pigouvian tax than reducing output: move to another location, switch the technology or the type of the product, bribing the damaged person to leave the location, asking the damaged agent to compensate the polluter, pass the tax burden on to others etc. In the macroeconomic analysis these modes of evasion are unlikely to work.

If *environmental technological progress* is introduced, emissions would fall while output and employment remain constant. Further output growth would require increase in etp in lockstep, or faster than output. If degrowth or zero growth, only in some countries or even

globally, should be avoided, prudent innovations need to be promoted and implemented. “Prudent” are those innovations in the field of ecology, that have no or only little negative side effects so that the old-fashioned term “technical progress” truly applies. The history of technology demonstrates overwhelmingly that progress often came along with negative external effects, and even at grand scale with time lag. Pure progress is rare. Ambiguity predominates. The evolution of the global greenhouse effect is a case in point. Extraction of fossil fuels and their burning in industry, energy production, traffic and housing in blind disregard of the limitations of the absorption sinks for CO₂ and other gases are telling. It is not only the lack or the belated advent of new technologies, it is also scaling-up of negative externalities in the course of GDP growth in the Global North and lagged even more forcefully in the Global South. Opening the water-gates for any kind of innovation and their concomitant rebound effects to catch-up with the rich and wealthy, irrespective of negative external effects, would be “imprudent technical change”. With hindsight, “technical progress” in the past and present was and is highly overstated. From an environmental point of view, *fake technical progress* had been predominant since the industrial revolution. Often such innovations are in their consequences ambiguous: they reduce costs and improve the use value of products, but trigger negative externalities to an extent that is initially unknown or uncertain and depends to a strong extent on the scale of the usage of the innovations. Standard neoclassical growth theories, but also other growth theories, including post-Keynesian, ignore negative externalities or assume implicitly they can be managed in a welfare-enhancing manner.

The dynamics of innovations abet *short-termism and myopia*. Technology impact assessments regarding innovations are seldom, if we exclude the pharmaceutical industry. Ex post regulations are difficult to implement due to vested interests. Pigouvian taxes, based on expected damages, would dampen the speed of innovations, retard economic growth and threaten employment. The full knowledge about potential negative external effects emerges often with delay and is often so complex that optimal taxes cannot be installed. Technology standards or minimum technical requirements seem more effective instruments despite downsides. Taxes may be a supplementary instrument.

In orthodox economic theory, the intertemporal allocation of resources is believed to depend on the *time preference* which in turn determines long-term real interest rates. If economic myopia is widespread, *interest rates* could, in principle, be lowered by the state or the state-owned central bank. Thus, the present value of future damages would increase which could function similar to an eco-tax. However, prospective benefits will also rise in terms of present values so that the effect of low interest rates is neutralised. In reality risk-neutral long-term interest rates depend strongly on (expected short-term) central bank rates, which depend on their part mainly on inflation expectations and the country’s risk premium – to cut a long explanation short. For the state, the often-complained short-termism of governments follows mainly the prevailing political system. Hence, *Pigou’s ideas can hardly influence myopia*, an important driver for negative externalities, especially if the latter cumulate and thereby potentize the negative impact.

2.3. Summing-up

So far, we have shown that Pigouvian taxes do not hold what is promised. They may not be fully ineffective, but the macroeconomic view on these taxes nourishes doubts about their effectiveness. This holds first and foremost true if there is no or only limited availability of technology to replace the old one, or the usage of the old production technique or product quality is path dependent, for instance due to an old long-lasting capital stock or a stock of human capital. Small technology changes may prevail over big leaps by basic changes as discussed in theories of long waves in the Schumpeterian tradition (e.g. Kondratieff-cycles). Much depends on whether or not different production techniques or new product quality are triggered by the tax. Often other technologies are available or need only little change, in other cases new technologies or materials are needed. The prevailing simple rationale is that relative prices determine the technology to a considerable extent. Despite a higher price of the green product consumers or producers purchase the new product since this is less costly than paying the tax. This may be the case, but is bound to very specific conditions. Major technological change often faces resistance, in contrast to small changes. There may be cases where externalities perfectly fit Pigou's ideas, but it seems illusory that grand scale taxes can do the full job assigned to them. To become effective and efficient in the same vein they might need specific supplementary measures. In the case that no new technology is needed for reducing negative externalities, but behavioural change suffices. Using bicycles instead of cars or quitting smoking are examples. Both examples are of the win-win type, external costs and at the same time internal costs shrink in tandem. Welfare increases without costs. Actually, Pigouvian taxes are not needed, but they can trigger the change of the behaviour. If the environmental benefit or the avoidance of harms is valued high, supported by enlightenment, they may be even accepted if costs of avoidance need to be occurred. From an economic point of view these are low-hanging-fruits, doubly prudent in economic and ecological or medical terms, but not necessarily easily implemented seen through a psychological lens.

Let us briefly look at five cases of potential Pigouvian taxes: taxes on tobacco, especially cigarettes, on air tickets, on gasoline, on beef and a carbon tax on fossil energy. The damages and the harm, hence the negative externalities and the social costs caused in all examples seem unambiguously considerable or even immense as in the last example. With the exception of the carbon tax, the taxes are imposed on consumers directly or passed-through by design onto consumers. The price elasticity of demand is limited in all cases, but will rise with the tax rate.

In case of tobacco, the Australian government was enormously successful with very high taxes, almost prohibitive, combined with outright prohibitions (e.g. domestic production of tobacco not allowed, harsh no-smoking regulations). Nothing is known about other drugs as substitutes.

Taxes or fees on air tickets exist already to a considerable degree (although not for environmental reasons), but not a tax on kerosine; international regulations might be necessary. Price elasticity of demand differs strongly among passenger groups, for many it is high, for well-to-do passengers rather low. Up to a threshold, taxes could be effective, especially on domestic flights, but require other means of transport, especially trains. Increase of car traffic might be an unwanted side effect. Sometimes cutting direct or indirect subsidies suffices to reach considerable impact. For long-distance business flights, eco taxes would likely

meet inelastic demand. In general, effectiveness depends strongly on behavioural change, but also on new aviation technologies.

Similar holds true for gasoline taxes, if other traffic systems exist, in particular bikes and public traffic. Otherwise, taxes are obverted from steering to revenue making. Complementary infrastructure is needed, hence local government expenditures.

There is little empirical evidence on taxing beef, whose consumption contributes strongly to methane emissions. Most likely the price elasticity is fairly high since alternative meat products exist (e.g. poultry). Behavioural change is important which could be triggered by a tax, including elucidation on the issue. Key precondition for a tax on beef are regulations to bar imports, similarly in the other cases.

The carbon tax is imposed on producers of goods with fossil-based electricity as a key product with strong input-output interdependencies. Production of investment goods, intermediate goods and consumer goods and services is affected. The tax is spread pervasively in all sectors of production and final consumption. But the scope for responses by final consumers is limited if technological and infrastructural limitations exist so that alternatives regarding green energy and products incorporating green energy cannot be generated by the consumers, i.e. private households. Hence, the switch to other or new technologies, often much more expansive than brown technologies would in many cases require high and very high carbon prices. The shortcomings of Pigouvian taxes in this respect are much heavier than in the four previous examples. Very high taxes with small and even basic changes of technology trigger grave consequences for infrastructure, finance (public and private) and last not least income distribution. Societies are extremely sensitive to strong changes of income and wealth distribution, especially if they occur suddenly, unexpected and with high uncertainties. The latter is even enlarged if it comes with international repercussions due to the impacts of the carbon-tax on trade and capital mobility. Since the open window for change is limited, speed of action is urgent. Social acceptance of change is at risk. In brief, a carbon tax differs strongly from the first four Pigouvian taxes.

In the first four cases Pigou-taxes are likely to work effectively, but only under a set of regulations which go close to prohibition as in the case of tobacco. Also, behaviour of consumers must – and likely could – change. This implies that not all negative externalities would be erased, but a relevant share. Internalisation of external costs is probably incomplete, but this would require a detailed estimation of costs. In these examples the taxes could be implemented without severe macroeconomic negative consequences, but induce fewer social costs. The primary effect is likely a reduction of GDP, but this might be compensated by additional governmental expenditure of the revenues. Insofar the taxes are not pure steering taxes which shrink to zero if fully effective, but have side function as revenue-earning taxes. They function without knowing the precise costs of the “bads” which are reduced, and the optimal Pigouvian tax cannot be calculated but a certain degree of reduction of the harms might be considered as sufficiently successful.

Now we turn to the fifth case, carbon taxes, in more detail.

3. Carbon taxes against global warming

Pigou's analysis is not more than a special case of microeconomic price theory under perfect competition: the price of goods equals marginal costs, and the latter should include total social costs, hence also external costs reflecting the marginal costs of the damage. The optimal tax leads to a Pareto optimum since the damaged agent benefits marginally more than the tax the polluter has to pay. The marginal costs of the damage may be the costs of the partial repair or a mere financial compensation or the costs of reducing the quantity of emissions, often in line with less output. Complete prevention of the negative effects does not take place since the damage is not worth it. Hence the cost curve has a positive slope. Implicitly the damage can be partially eliminated, technically or by reduced output. If the entire damages have to be avoided or compensated, the cost curve is on every point above the output-emissions-line. Then the optimal tax is prohibitive, output must be curtailed to zero. If this case is excluded, Pigou seems to imply that either some kind of appropriate technology exists or that some degree of output reduction is feasible and enforceable.

The *usage of the revenue* from the tax is not addressed by Pigou. Even if it were saved by the authorities the Pareto improvement would occur. From his welfare theory we know that a redistribution to low-income receivers would enhance social welfare, but this is beyond his price theory. The idea is that the Pigouvian tax revenue is zero because it is a steering tax that leads to an optimal allocation with fully internalized costs. Time-lags of damages, measuring problems of damages and cumulating or even irreversible damages (such as health issues and mortality) are not addressed. If the imposition of taxes is bypassed by the Coase-theorem which calls for negotiations between polluters and the damaged persons, these problems can possibly be overcome by financial compensations, but this would be environmentally ineffective. Positive externalities are mentioned by Pigou, but they play a minor role since firms tend to avoid them by internalization. If they nevertheless occur, the state should subsidize firms. The nucleus of industrial policy shows up.

The specifics of climate warming go in this direction:

- emissions from Greenhouse Gas (GHG) are irreversible and cumulate; they are caused by systematically shifting costs on future generations, initially in face of ignorance or limited knowledge about the limitations of nature, later by culpable negligence and favoured by strong incentives for dirty technical change misconceived as technical progress;
- they are a global problem but there is no global state to install global Pigouvian taxes; or similar policies;
- the global negative external effects, a grand market failure, are specific types of externalities – they are a special case of the “tragedy of commons”, namely the atmosphere, the oceans, tropical rainforests and other large sinks;
- the negative external effects came with a long time-delay before their growth accelerated; the residual budget has shrunk rapidly so that marginal costs rise at a level far beyond measurement; action has to be taken timely, the window of opportunity is short;
- the emissions have to be reduced close to zero, following the Paris Agreement; measures can be taken gradually but the final goal is prohibition so that the marginal cost curve moves strongly upward which requires prohibitive taxes which may cause global degrowth

if appropriate technology were not available; however, heavy degrowth on a global scale with mass poverty could aggravate externalities;

- much of the anti-pollution technology is already available, but an important part, especially regarding big, quasi-revolutionary innovations does not yet exist; new technology and also new and larger specific infrastructure play a greater role than in most other externalities;
- a large part of the global capital stock needs to be devalued and replaced by a green one; the ample reserves of fossil fuel must remain under the ground, untouched, and become devalued;
- the costs of devaluing old fossil assets and creating a renewed capital stock are immense, and must include the Global South; additional finance is required, a problem not addressed by Pigou;
- the transition period itself might trigger global output growth which reinforces negative externalities, especially if fired by the wishes in the Global South to catch-up with the Global North. Huge North-South conflicts might be looming, although both blocs sit in the same boat.

The peculiarities of the global greenhouse crisis make the application of Pigouvian taxes as the only or the chief weapon in the battle against global heating impossible or less effective. Eight arguments stand against this approach:

1. The final goal is reaching net zero global emissions by the mid 21st century, thus a *de facto prohibition*. Pigouvian taxes are not designed for prohibition. To achieve the goal, CO₂ taxes have to be imposed globally, but gradually at an ever-increasing rate. The tax will not be paid if emissions are reduced, but this is supposedly a long process during which global output becomes more expensive.
2. Pigouvian taxes are designed to internalise external costs of production in the present period. Pigou disregarded the *stock of accumulated irreversible damages* emitted in past periods by former polluters that can no longer be taxed. These externalities cannot be internalised any more. Therefore the speed of pollution abatement of present and future emissions has to be accelerated.
3. The carbon tax as the chief instrument might *trigger inflation* and fires general price increases. If revenues from the tax are returned to citizens, it will provide an aggregate demand impulse to the supply-side inflation.
4. The targeted *change in relative prices* will be diluted due to large-scale pass-through of the carbon tax. Diminished change of relative prices dampens the substitution of green for brown energy.
5. Technical progress is more than substitution and requires research & development and support in mass diffusion of new technologies. *It is unlikely that basic innovations occur due to the tax*: it may function as tail-wind for change, but innovations, especially fundamental ones, require a chain of changes in the entire value-chain. Empirical studies show that the link from carbon taxes, even taxes on gasoline, do not necessarily trigger major innovations. Studies show that small or no innovations prevail (Lilliestem et al. 2021). From a Schumpeterian perspective, it is the power and the initiative of entrepreneurs who set innovations in motion.

6. The costs of climate externalities are *impossible to measure*. For Pigou this was a key prerequisite. In the design of cap-and-trade systems, based on the aim to steer the aggregate quantity of emission permits, i.e. supply, which leaves the prices up to demand; the price trend is hardly foreseeable, especially since the basic world market prices fluctuates. The latter can neutralise, diminish or reinforce the price effects due to CO₂ taxes. If price ceilings and floors were prescribed while the quantities are planned, discrepancies of supply and demand emerge which are difficult to smooth (see Edenhofer 2021).
7. If the *political economy of decarbonisation* is included in the analysis, one has to observe how the owners and sellers of fossil fuels, in particular OPEC+ (including the Russian Federation), and the big global gas and coal suppliers respond to carbon taxes in OECD countries. The U.S. are the largest natural gas and also the largest crude oil producer on the globe, China has the largest coal production among all countries. If the taxes are effective so that less fossil fuels are used, they might respond with lower prices on the world market; they could also try to curtail the supply in the course of the transition in order to indulge in price booms before fossil fuels fade away. Of course, key for the functioning of carbon prices is avoidance of leakages in international trade which would undermine the national cap-and-trade systems. A uniform global CO₂ tax or a global cap-and-trade system seems to be out of reach. This would be the crucial precondition to achieve cost efficiency so that emission reduction occurs first and foremost in countries, sectors and firms where abatement can be done most cheaply.
8. Internalisation of externalities requires a well-informed and active state capable to impose eco-taxes, in Pigou's time a nation state. If the pollution is a global problem, a *global state* or globally concerted action is a precondition.

These arguments are not put forward here to refute carbon taxes. Rather, complementary policies out of a broad arsenal are needed (see also Krebs 2021 and Claeys et al. 2024): R&D and industrial policy, public infrastructure, special human capital, transition finance, trade policy, financial sector policies that discriminate against fossil industries and the respective mega firms. To be effective, they require positive external effects from targeted R&D, industrial policies focused on the energy sector and the key producers of carbon-intensive goods (such as steel and cement, basic chemical industry) and the respective customers of carbon intensive goods (like car making, machinery, construction) etc. Since all these changes eventually change relative prices and relative costs, and the costs are at the end of the day to be borne by private households, there will be strong effects on income distribution which require redistribution to those who have to carry high costs relative to their income and wealth. Otherwise, the entire transformation of the economies is at risk if acceptability falters and "fossil populism" wins the battle of ideas for the future of humanity.

4. Can industrial policy with subsidies achieve more than Cap-and-Trade systems?

If both producers and consumers of negative externalities are considered as responsible polluters of global warming, both groups would have to be targeted with Pigouvian taxes. Then all citizens – or agents, meaning firms and households - have to pay for mitigation and

adaptation. Taxpayers have to pay the bill for abatement and are subject to CO₂-taxes. This implies that firms as well as households receive taxpayers' money for the support for decarbonisation. The same occurs if firms and households were levied with Pigouvian taxes, either directly or by pass-through to consumers. The revenue from this taxation is considerable and must not to be ignored as in the microeconomic model of an externality. Therefore, proper spending of the revenue is as important as the proper tax rates and the proper quantity of emission certificates. This view leads us to industrial policy for decarbonisation in a broader sense, including firms and households in the form of subsidies and transfers. This view includes also transition finance, such as sovereign green bonds, guarantees or other forms of preferential treatment.

Furthermore, if positive externalities emerge from green innovations that can speed-up substituting fossil energy by renewables or energy conservation including the formation of green infrastructure, this view on Pigouvian taxes is much more prolific than the traditional one. In the latter, the usage of revenues, transition finance and the promotion of positive externalities with Pigouvian benefits are included and integrated. The difference is however that the state has much more power and freedom to operate than in a regime of normal Pigouvian taxes.

From this angle, the apparently sharp differences between the U.S. approach to climate policy under the "Inflation Reduction Act" (IRA) tailored by the Biden administration and the European Union's preference for the Emission Trading System (ETS) with a dynamic Cap-and-Trade system become blurred. It should also be kept in mind that ETS-system seems to abet pervasive pass-through in downstream direction to consumers, while IRA could focus industrial policy – if managed properly – on key areas of technological bottlenecks. As is well-known, the highest CO₂-content is incorporated in a few industries and products, such as heavy and chemical industry products like cement, fertilisers, aluminium, steel and grey hydrogen, let alone international traffic (air and sea). The focus on specified products and technologies is stronger under IRA than under the ETS. Last not least, the inflation problem and the popular acceptance seems to be more favourable with respect to IRA. Perhaps the advantages of both systems can be synthesised.

The border adjustment problem remains an open problem in both regimes of decarbonisation.

5. Conclusions

The externality of the greenhouse effect is a very special one: the scale is global and rooted in all economic sectors and value-chains; it is based on global commons and harms present and many future generations; past emissions are irreversible, meaning previous polluters cannot be included in internalisation measures; present and future damages are virtually impossible to be measured in an unambiguous manner; emissions and respective damages accumulate so that costs per tonne of CO₂ (and other gases) are rising; almost all emissions have to be stopped by 2050 which amounts to a prospective prohibition which would require prohibitive prices or an outright ban, beyond a Pigouvian tax; almost all goods are infected with carbon directly or indirectly so that a high carbon price would affect all prices as long as substitution

is limited or proceeds gradually; polluters can pass-through the carbon tax to some extent to customers, eventually final consumers.

Pigou's theory of negative external effects is essentially microeconomic. In this theory, polluters can be identified as well as cost curves, so that optimal taxes can be calculated and levied on them. International leakages do not exist. The tax is a steering tax, not a tax to generate revenues. A successful Pigouvian tax will never be paid. The causers of the harm can change their mode of production, curtail their production or pay a compensation to damaged people. In the case of the climate problem, emissions have to be reduced close to zero. Mere financial compensation or only a partial reduction of emissions is not in line with the Paris goals. Change of technology, hence full substitution is needed if cutting output, i.e. degrowth is to be avoided since this might trigger even more emissions. The change of relative prices remains limited, even with high carbon prices, since all prices for products that contain carbon rise. A strong rise of global carbon prices over an extended period could trigger long-standing inflation. It might also be questionable whether the carbon price can be controlled by a Pigouvian tax, if an influential group of fossil-fuel owners and firms that process these fuels and trade them push for higher or lower oil, gas or coal price on the world market and thus undermine carbon taxing in the "climate policy club" of countries.

For all these reasons, decarbonisation needs more economic policy instruments than relying only on carbon pricing. Key is changing the production system from brown to green technology. This requires focussed industrial policies, research & development which triggers positive externalities, infrastructural policies of grand scale which enable transformation, low-cost finance for green investments by households and firms and foreign aid for developing and emerging economies. Furthermore, due to broad price changes as a consequence of the green transformation, the income and wealth distribution will change. Critical disruptions must be avoided in order to guarantee broad acceptance of the changes. Getting the prices right does not suffice in the battle against global warming. Pigou is not the master mind for the 21st century. Yet, his heritage can be included in a broader policy mix.

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