Chapter 7

Conclusions

7.1. Recap of findings and their policy relevance

This dissertation has primarily focused on the efficient design of urban tolls in the light of recent double dividend theory advances. That theory was modified to take the spatial dimension into explicit account. The insights from Chapters 2, 3 and 5 are useful to planners and policy makers, because they shed light into the way different policy instruments interact with congestion taxes. In an era in which urban tolls begin gaining momentum, these insights provide estimates of the extent to which policy agendas that were previously confined to produce separate solutions by separate authorities (urban planning principles, transportation planners, local and federal governments) will have to merge or be restructured in order to provide efficient solutions to congestion externalities. To some extent, the interactions between road taxation and other policy instruments, most often controlled by heterogeneous authorities, had been examined by contributions prior to this work. But the critical difference is that the work in this dissertation investigated the interactions of interest by treating space explicitly. This led to a set of novel policy-relevant insights.

Chapter 2 derived two such insights, both highlighting the importance of spatial variation in the elasticity of labor supply. In general, earlier research in non-spatial settings showed that a high elasticity of labor supply may render marginal external cost pricing (a quasi-first best policy) welfare-decreasing. Chapter 2 highlighted that, in a monocentric setting where the above elasticity falls with distance from CBD, a cordon toll may generate welfare gains even when the quasi first best scheme causes substantial welfare losses. The finding has substantial policy implications, since it highlights conditions under which an archetype second-best scheme can be proven to be superior to a Pigouvian scheme, whose informational requirements and implementation costs are very high.

The other policy-relevant insight of the chapter pertains the key role congestion pricing can play in a distorted, and thus inefficient to begin with, tax system. When road toll revenue is used to finance labor tax cuts, road pricing is shown to provide welfare gains even in absence of congestion. This can extent to any setting in which the magnitude of the distortion caused by a spatially-uniform tax (e.g. on commodity A) varies over space. The finding highlights that an efficiency-enhancing mechanism may be established with an arbitrary space-varying tax (e.g. on some other commodity B) if the revenue from the latter tax (i.e. B) is used to finance a cut in the former (i.e. A). Furthermore, the finding shows that the introduced space-varying tax does not have to be an externality tax: even a distortionary tax could serve as a candidate, as long as it
varies over space and is less distortionary (i.e. it is associated with a smaller marginal excess burden) than the pre-existing, spatially-uniform tax.

Chapter 3 provides further insights regarding how interactions between externality taxes (e.g. congestion taxes) and regulatory mechanisms (e.g. zoning regulations) affect the efficient design of a tax system. Like pre-existing distortionary taxes, command-and-control regulations affect the welfare gains that externality pricing could bring. But an important difference is that, whereas tax-induced distortions invoke deviations from the Pigouvian tax rule in the primary market (i.e. the optimal tax deviates from the marginal external cost), such deviation is not efficiency enhancing in the case of quantitative restrictions (command-and-control regulations). The findings of the chapter bear significant policy implications, because they highlight the conditions under which road demand management can be detached from urban planning and public finance decisions. The policy relevance lies on the fact that authorities in charge of the respective policy instruments are horizontally and vertically scattered in the governmental structure. More important, these implications are general: it is shown that the answer to whether generic externality taxation must consider a deviation from the marginal external cost does not so much depend on whether distortionary policies in related markets exist, but much more on the type of these distortions.

Focusing on monocentric cities with identical household preferences and road technologies but different levels of stringency on the maximum building height, the chapter provides an extensive sensitivity analysis of the Pigouvian congestion tax welfare gains. That analysis explores the extent to which gains from congestion charges for cities without any housing regulation (as commonly assumed in the literature) can be extrapolated to cities with restrictive land-use regulations.

Chapter 5 derives insights from the interaction of congestion taxes with the pre-existing distortionary labor tax in a polycentric, mixed network. First, it is shown that a system of cordon tolls may not be welfare enhancing without a sophisticated revenue-recycling mechanism that reduces the distortionary tax. The models used in Chapter 2 and 5 are calibrated to fit similar stylized facts. However, in a polycentric setting the distortionary effect of the pre-existing tax does not vary monotonically over space. As a result, cordon tolls do not impose an indirect labor-tax to the most inelastic part of the labor force, as it was the case in the monocentric city setting of Chapter 2. The key implication is that, in a polycentric conglomeration, an efficient revenue-recycling mechanism is more important compared to a monocentric setting.

Is this mechanism, together with knowledge over the marginal external costs of congestion always enough to guarantee welfare gains? The findings of Chapter 5 disprove this statement. It is shown that, in the base calibration, a full-network Pigouvian toll (marginal cost pricing) combined with labor tax cuts produces a welfare loss. The intuition behind this result is that most of the link-specific optimal tolls (which are computed for the entire network) lie far below their Pigouvian levels, with a significant part of them (the links that contain the most elastic labor suppliers) receiving a negative charge. In these links, the introduction of a marginal
toll may aggravate the labor market distortion enough to offset both the benefits from congestion relief and the reduction of the uniform labor tax the additional road toll revenue can finance.

The policy message of Chapter 5 differs significantly from that provided in Chapter 2 in at least two ways, reflecting the importance of network configuration in the analysis. First, a system of multiple cordon tolls produces welfare gains only with revenue recycled in the form of labor tax cuts. Second, even then the welfare gains are small, a finding that is robust across thorough sensitivity analyses with respect to the model’s parameters. These differences stem from the reduced capability of cordon tolls to: (i) tax eclectically the network users that generate the weakest tax interaction effect and (ii) capture external congestion costs in a polycentric network. However, further sensitivity analysis with respect to the underlying labor market distortion shows that the system of cordon tolls may be a viable remedy in lower labor tax levels. As the background labor tax falls, the optimal charges converge to their (strictly positive) Pigouvian levels, restoring gradually the efficiency of all archetype second-best schemes. With the labor tax completely eliminated, it is shown that the efficiency of the proposed cordon toll system is in accordance with values provided by studies focusing on the properties of the cordon toll in polycentric settings without regarding the labor market distortion.

In addition, Chapter 5 highlights that non-marginal, revenue-neutral tax swaps between externality and distortionary taxes may be welfare-reducing even if the underlying externality tax scheme is optimal from an environmental point of view. Therefore, two policy components that would be considered to be optimal in two separate settings, i.e. a Pigouvian tax (that would be optimal in a setting with space but without parallel distortions) and a horizontal-by-default labor tax cut (that would the default optimal way to recycle the externality tax revenue in a spaceless world) may turn out to be detrimental when combined in a third, interim setting that includes both space and a parallel distortion. The findings of Chapter 5 may motivate more sophisticated policies, whose optimal design is based primarily on complex fiscal information (i.e. the distortionary impact of the externality tax adjustment) rather than environmental information (i.e. the abatement effect of that adjustment). These policies are not exhausted in adjusting the levels of the externality taxes (above or below their Pigouvian levels); they may also expand to more complex revenue-neutral tax swaps, in which the cut in the distortionary tax may be spatially differentiated. The feasibility and welfare impacts of such exotic policy options may be investigated in depth in future work.

The peripheral focus of this dissertation concerns the fiscal externalities of horizontal toll competition. Chapter 6 provides numerical computations for the social cost of a decentralized, i.e. locally-autonomous toll system in a polycentric conglomeration. The findings show that toll competition in terms of local welfare may reduce overall utility, but it could favor the large area whose links are used widely (and asymmetrically) by residents of the smaller region. When the objective shifts to revenue maximization, both regions are found to end up with much higher toll levels and are worse-off compared to the no-toll equilibrium. These decentralized settings are juxtaposed against two centralized cases, in which the kilometer tax is set by a social planner who aims to maximize the average utility of the two regions. In these social planner settings, the
kilometer tax can (in the latter case) or cannot (in the former) be differentiated across the two regions. In both cases, the resulting allocation is found to be Pareto-preferred to the no-toll equilibrium by both regions.

7.2. Recap of the methodological contribution

Apart from the main findings and their policy implications (summarized in Section 7.1), the dissertation contributes in understanding the structure and in enhancing the computational efficiency of General Equilibrium models of Land Use and Transport (GELUT). This tool is one of the few consistent options in modeling polycentricity in a non ad hoc way. GELUT models have been used in Chapters 4, 5, and 6.

Chapter 4 focuses on the complex and large scale nature of GELUT models and highlights why their accurate and fast solution by numerical methods is an important issue. It provides the specification of two candidate solution approaches and the detailed anatomy of the respective algorithms. The first approach is based on an all-in-one algorithm that solves for the economic (land-use) and stochastic user equilibrium simultaneously. The second is based on an iterative-shortcut approach, in which the algorithm (i) iterates between the two equilibria and (ii) reduces drastically the computational burden associated with the economic equilibrium. Comparative analysis of the algorithms shows how and why the latter approach can provide from significant to enormous time savings. The analysis involves decomposition and inspection of the separate components of each algorithm and illustrates how computational time savings evolve as a function of the model’s network resolution (i.e. the number of zones and links). The final part of the chapter identifies the conditions under which the two formulations are fully equivalent, i.e. they represent the same model, with the respective solution algorithms reaching the same equilibrium. Detailed design patterns, schematic depictions and pseudocode disengaged from any programming language are provided throughout the chapter.

7.3. Future challenges

Several extensions of the material included in this dissertation may bear significant policy-relevance. Some of these extensions regard the “real-world” magnitude of the tax interaction effect and its spatial pattern. Obtaining a measure of it could prove particularly useful: the careful reader understands that the above effect, which is co-determined (with a large number of endogenous variables) by the spatial lay-out, network configuration and multiple policy instruments, is the key to predict whether conventional pricing schemes are destined to produce efficiency gains. Therefore, what is needed is extensive empirical work to identify the causal effect of different types of road taxes on the labor tax base and obtain estimates of its magnitude. A similar argument holds for the effect congestion charges exert upon the property tax base.

At the same time, future modeling work may focus on the construction of less abstract simulation models that introduce a series of behavioral margins playing an important role in the determination of the tax interaction effect. Elastic labor supply in the intensive margin is perhaps
the most important ingredient to be incorporated in future studies. Two model modifications can be of interest. First, the ability of the worker to adjust the duration of the working day simultaneously with the number of working days. This is a reasonable assumption to make since nowadays a significant number of professions are enjoying more flexible working hours. Second, the possibility of the commuter to adjust the departure time in order to avoid peak period congestion and the respective congestion charges.

In the context of the models used in Chapters 2-6, none of these extensions is straightforward. The former requires modified preference relations and production functions that facilitate the endogenous determination of the value of leisure time (throughout day $x$) and the marginal product of labor supply (throughout day $x$) as a function of the working day duration. Then, the duration of working day could be determined through an equation of these two. The labor supply in the extensive margin could be decided through a similar trade-off and the explicit incorporation of a budget constraint. Endogenous departure time in a general equilibrium model with bottlenecks is also a challenging extension because it requires technologies and preferences to be modified in order to produce endogenous values of leisure time at home, queuing time, commuting time, as well as schedule delay costs.

A substantial part of the thesis contributes in developing further and understanding better what was (in this work) named as General Equilibrium models of Land Use and Transport (GELUT). As explained in Chapter 4, these models possess unique elements that facilitate detailed, non *ad hoc* policy analysis at the urban level. Future work in the GELUT framework will not be limited to the design of congestion taxes. The environmental effect of spatial planning instruments (*e.g.* zoning regulations, land-use tax-based instruments) and the impact of drastic technologies (autonomous vehicles and automated highways) on the urban form and the environment are timely research questions to be explored with the above family of applied models.

To facilitate this work, two methodological contributions in the GELUT framework are needed in the near future. The first is the development of expected-utility maximization algorithms that handle the problem of income effects in large scale GELUT applications, as it has been highlighted explicitly in the stylized setting by Anas (2012). The second contribution is more challenging and pertains the forecasting power of GELUT models which, similar to other general equilibrium models, is low. The infinite speed of adjustment, inherent in every equilibrium model, and the absence of market power contribute to this weakness. Dealing with these issues is not an easy task, as the above elements are intrinsic mechanisms that identify a general equilibrium *per se*. However, part of the problem could be circumvented by adding more detail in the behavioral elements that drive the actions of the main actors in these models.