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Three essays on the sectoral aspects of economic policy

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To my parents.

"Je ne pense pas qu'il soit nécessaire de savoir exactement qui je suis. Ce qui fait l'intérêt principal de la vie et du travail est qu'ils vous permettent de devenir quelqu'un de différent de ce que vous étiez au départ Si vous saviez, lorsque vous commencez à écrire un livre, ce que vous allez dire à la fin, croyez-vous que vous auriez le courage de l'écrire ? Ce qui vaut pour l'écriture et pour une relation amoureuse vaut aussi pour la vie. Le jeu ne vaut la chandelle que dans la mesure où l'on ignore comment il finira."
(Michel Foucault)

"I don't feel that it is necessary to know exactly what I am. The main interest in life and work is to become someone else that you were not in the beginning. If you knew when you began a book what you would say at the end, do you think that you would have the courage to write it? What is true for writing and for love relationships is true also for life. The game is worthwhile insofar as we don't know where it will end."
(Michel Foucault)

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Introduction

In this thesis, I study the implications of policy with heterogeneous sectoral impacts in three separate research fields of macroeconomics: *(i)* environmental policy, *(ii)* foreign aid and *(iii)* the political economy of the twin deficits. Through the three chapters of this thesis, it will be argued that, in all these three contexts, the sectoral impacts of policies play important roles in the policy evaluation and in the determination of optimal policy.

In the first chapter, co-written with Baris Vardar, the policy of our concern is the pollution tax which causes different impacts on the sectors with different pollution intensities. More precisely, an increase in pollution tax induces a reallocation of resources from the sectors with more pollution intensity to the sectors which are less intensive to pollution. The inter-sectoral reallocation of production factors, and its associated impact on factor prices, leads the households with heterogeneous endowments of the resources to have different preferences toward the policy.

In the second chapter, I study the macroeconomic impacts of foreign aid and I consider two sectors of tradable and non-tradable. Foreign aid, as a form of windfall income, decreases the competitiveness of the tradable sector (henceforth, T-sector) and leads to a flow of resources from the T-sector to non-tradable sector (henceforth, N-sector). I demonstrate that this inter-sectoral reallocation of resources has crucial impacts on the effectiveness of foreign aid and it can influence the optimal form of foreign aid and the policies which must be implemented by recipient economies.

In the third chapter, I consider the same sectors as in the second chapter: T-sector and N-sector. The focus of this chapter is rather on the political economy of the twin deficits: a deficit in current account induced by a deficit in fiscal balance. An increase in the two deficits induces the same sectoral effect as foreign aid does in the the second chapter: a reallocation of resources from the T-sector to the N-sector due to a decline in the competitiveness of the former. However, contrary to the second chapter, the resources (labor in this chapter) cannot flow freely from one sector to the other. Due to this friction, households affiliated to different sectors will be differently affected by the twin deficits. This leads to different policy evaluations by households affiliated to different sectors. The arisen heterogeneous policy evaluations motivates the political economy framework of this chapter.

In all the three chapters, the important roles played by the sectoral impacts of the policies are due to a sort of externality. In the first chapter, the disutility of pollution is the source of externality: neither firms, when deciding about the reallocation of production factors between the two sectors, nor households, when consuming final good produced in different sectors, take into account the disutility of pollution arisen by the pollution-intensive sector.

In the second chapter, the source of externaliy is Learning-By-Doing (henceforth, LBD) effect generated mostly by the T-sector: a shrinkage in the T-sector deteriorates the growth. Neither the government, nor households do not take into account the impact of their consumption choice on growth when they reallocate their resources between the final goods produced in different sectors.

Finally in the third chapter, the friction in the labor market is the source of externality: If the labor market were frictionless, a variation in the twin deficits would not have asymmetric impacts on the households in different sectors. Thus, households would have had symmetric policy evaluation and there would have been no room for a political economy framework. In the following paragraphs, I will briefly explain the motivations, the methodology and the main results of each chapter.

Chapter 1

The first chapter of this thesis which is co-written with Baris Vardar focuses on environmental fiscal policy and it investigates the distributive implications of green taxes. More precisely, this paper answers to two main questions: (i)"among the households with different levels of capital endowment who are more likely to support a higher level of pollution tax?" and (ii) "what is the effect of a household's capital endowment on his support for environmental protection?". The importance of these questions relies on the necessity and the emergency of having national and global agreements on environmental policies - such as pollution tax. Agreements on environmental policies are inevitable for confronting the menace of climate change and global warming. However, the possible asymmetric impacts of environmental policies on heterogeneous households can induce serious obstacles to achieve such agreements: if heterogeneous households are differently affected by environmental policies, then they will support differently these policies. The heterogeneous policy evaluations is especially important when a political economy framework that aggregates different policy preferences is taken into account.

This potential barrier has motivated some environmental economists to study the asymmetric impacts of environmental policies on the households with heterogeneity in different dimensions. For example, Chiroleu-Assouline and Fodha (2014), Fullerton and Monti (2013) and Marsiliani and Rengstrom (2002) study the effect of environmental policies on the welfare of households with heterogeneity in terms of labor income. Fullerton and Heutel (2010) and Rausch et al. (2011) study the heterogeneity in terms of income transfer and Borissov et al. (2014) could be given as an example that studies the heterogeneity in the discount rates of households. This chapter contributes to the exiting literature by focusing on the heterogeneity in terms of wealth endowment.

The heterogeneity in terms of wealth endowment can play an important role in regard to the determination of and the support for environmental policies. The rich households in top percentile incomes have usually very influential political power to affect the policies that are chosen and implemented by the government. If this part of the society support less environmental policies, then higher wealth inequality can be barrier for improving the environmental protection. In a recent empirical study, by using micro data from European Value Survey (EVS), Ercolano et al. (2014) show an inverted U-shaped relationship between households income and their support for environmental protection. This means that for households in the low and middle income deciles, there is a positive relationship between income and the support for environmental protection. However, for the highest income percentiles, the support for environmental policies decreases with income. What distinguishes the highest percentiles income from the the middle and low percentiles is the fact that the share of income coming from wealth, as well as the heterogeneity in wealth, is more pronounced in the former groups of households. The available from US show that the fraction of income that comes from the capital is 5.7% for the lowest income decile, 7.8% for the fifth income decile and 45.6% for the highest income decile. This observation suggests that the different relationship between income and support for environment protection in the high income percentiles can be explained by wealth heterogeneity among the households in very high income percentiles. This motivated us to study the heterogeneous impact of pollution tax on households with different wealth endowment and to investigate the effect of wealth heterogeneity on the households support for environmental policy.

To pursue this aim, we build a static general equilibrium model that consists of households, firms and the government. Households have different wealth endowments and their utility depends on their consumption level and the level of environmental quality. The level of environmental quality depends negatively on the level of pollution created through production process. The production side of the model is inspired by the works of Harberger (1962), Copeland and Taylor (2004), Fullerton and Heutel (2007) and many others that adopts the international trade framework of Heckscher-Ohlin. We study an economy with firms that produce a generic good with the possibly to use two different technologies with each of them using capital, labor and pollution as inputs to produce the final output. We define the technology with higher intensity to pollution as dirty technology and the other one with lower intensity to pollution as a clean technology. The factor prices of capital and labor are determined endogenously in the equilibrium and the government determines the pollution tax.

Our results demonstrate that the impact of a pollution tax on the factor prices depends on the characteristics of the production technologies utilized by the firms in the economy. If pollution tax increases, labor and capital will be reallocated from the dirty to the clean technology. Consequently, the relative demand and so the relative price for the factor which is more intensively used in the clean technology will increase. The available data from US suggests that in general the dirty technologies are more capital intensive compared to the clean technologies. Relying on this data, we assume that the dirty technology is relatively capital intensive and the clean technology is relatively labor intensive. Consequently, we find that the relative price of capital to labor (net interest rate to wage income) will decline with pollution tax. In fact, our findings suggest that interest rate is always decreasing with pollution tax while the wage can increase or decrease with pollution tax. In particular, we show that the wage increases with pollution tax when the relative pollution intensity with respect to capital is higher in the dirty technology, and *vice versa*.

On the household side, we investigate the households decision on their preferred pollution tax and we identify a trade-off that they face between a higher consumption and a better environmental quality. We demonstrate that wealth endowment influences the preferred pollution tax of the households from two opposite channels. We call the first one the *satiation effect*. It says that households with a higher wealth consume more and their marginal utility of consumption is lower. Thus, they have more willingness to sacrifice from their consumption for a better environmental quality. We call the second channel the *income burden effect*. It says that households with a higher wealth have larger capital investments in the market. Thus, when the return of capital falls, their revenues are more affected by the pollution tax. Accordingly, whether the preferred pollution tax increases or decreases with wealth depends on which one of these effects dominates. We show that, in fact, this trade-off depends on the pollution tax elasticity of consumption that is determined by the pollution tax elasticities of the factor prices. More precisely, we demonstrate that the households with higher wealth endowment prefer relatively a lower pollution tax if and only if the percentage decline in interest rate is higher than the percentage decline in income wage. Relying on our results from production side, we show that this would be the case if and only if the dirty technology is relatively capital intensive. Therefore, our paper suggests that given the existence of an alternative labor intensive clean technology, the wealthier households prefer a relatively lower pollution tax. This result is novel in the literature and it can explain the fact that in high income percentiles, where the capital income share as well as the heterogeneity in wealth endowment is more pronounced, the rich reveals a lower support for environmental protection. Besides, this result has some implications on political economics of environmental protection. For instance, if the very rich households have high political power to influence the environmental policies then, wealth inequality can have negative impact on environmental protection.

Chapter 2

The second chapter of this thesis investigates the analysis of the relationship between foreign aid and growth. The macroeconomic impacts of foreign aid has been one of the focal points of interest in development economics. In the post-World War II era, capital transfers have increasingly taken the form of development assistance or foreign aid.[1] Several U.N. reports and declarations have called for a dramatic increase in Official Development Assistance (ODA) to achieve the Millennium Development Goals. Besides, EU has designed and implemented Structural Funds program to assist below-average per capita incomes and low growth rates member nations to catch up and transit into the union. Nevertheless, the relationship between foreign aid and the GDP growth of recipient countries has been questioned by many empirical studies (See Hansen and Tarp (2000) for a review) and there seems to be no emerging consensus on whether foreign aid can improve the growth in recipient economies.

The shortcoming of the empirical results in aid-growth studies is, to a large extent, due to the lack of rich and sophisticated theoretical frameworks that would identify the mechanisms through which aid affects the growth. This has motivated some economists to study the policies and parameters which can potentially turn the aid to be effective. The second chapter of this thesis aims to contribute to these theoretical efforts by introducing new factors which have not been taken into account in previous literature.

According to the existing literature, the most important channels through which foreign aid can improve the growth of the recipient countries are: (i) promoting the accumulation of private capi-

[1] See Brakman and Van Marrewijk (1998).

tal (Rosenstein-Rodan (1961) and Chatterjee and Turnovsky (2005)) and (ii) financing a higher level of public investment in infrastructure (Dalgaard (2008), Kalaitzidakis and Kalyvitis (2008) and Chatterjee et al. (2003)). On the other hand, the existing literature has identified the Dutch disease effect of foreign aid as a potential menace for the growth in recipient economies (Adam and Bevan (2006), Prati and Tressel (2006), Bevan and Adam (2004)). One contribution of this chapter is that it incorporates these three channels in a single model and investigates the interaction between them. Moreover, I distinguish and compare two different forms of foreign aid: *(i) tied aid* which is defined as an aid which is conditional upon being used to finance public investment and *(ii) untied aid* which is not conditional and can be transferred to the households in the form of subsidy or non-productive public services. Another contribution of this chapter is investigating the impact of the liberalization of capital market on aid-growth relationship. This dimension has not been studied in the previous literature. I demonstrate that liberalization of capital market can play an important role for the effectiveness of aid and, especially, for the comparison between the effectiveness of tied aid and untied aid.

To pursue these aims and to demonstrate the interaction between these channels, I establish a two-period general equilibrium model with two sectors: *(i)* Tradable sector (henceforth T-sector) and *(ii)* non-tradable sector (henceforth N-sector). To capture the effects of public investment and the Dutch disease, I allow for two sources of endogenous growth: *(i)* Learning-by-doing (henceforth LBD) effect generated by T-sector and *(ii)* the technological progress generated by public investment in infrastructures. On the one hand, foreign aid can increase the productivity of recipient economy by financing a higher level of public investment. On the other hand, aid can be harmful for the technological progress through de-industrialization which leads to a lower LBD effect. The de-industrialization is generated by the Dutch disease impact of foreign aid. To capture the impact of aid on accumulation of private capital, the model allows for endogenous saving. Moreover, I assume that private basket consumption consists of the final goods from the two sectors. Similarly, to provide one unit of public investment, the government must combine the final goods from the both sectors.

This chapter composed of two parts. In the first part of this chapter, I focus on the impact of *untied aid* on the growth rate of recipient country for two cases of open and closed capital market. The findings of this part suggest that in both cases of open and closed capital market, an untied aid leads to a shrinkage in the T-sector and, hence, to a deterioration of productivity through LBD externality. At the same time, united aid has a positive effect on private consumption and saving. If capital market is closed, then higher saving implies a rise in the accumulation of private capital. However, if the capital market is open, the deterioration in the next period technological progress leads to capital outflow. Consequently, for the case of open capital market, united aid diminishes the growth of recipient economy by deteriorating the technological progress and, simultaneously, by shrinking the accumulation of private capital. The impact of untied aid on growth is, however, ambiguous if the capital market is closed. The reason is that, on the one hand, united aid deteriorates the technological progress and, on the other hand, it improves the accumulation of private capital. I demonstrate that untied aid can improve the growth rate of a recipient economy with closed capital market if the LBD effect is small and private consumption is not very intensive with respect to the N-sector final goods.

In the second part of this chapter, I focus on tied aids. Similar to the previous part, two cases of open and closed capital market are studied and compared. Contrary to an untied aid, a tied aid can improve the technological progress of the recipient economy. This can be the case if the positive impact of tied aid through financing public investment dominates its negative impact through de-industrialization. I find that this condition holds if the LBD effect is relatively small and public investment is not very intensive to the N-sector final goods. Moreover, I demonstrate that if the impact of aid on technological progress is positive (defined as *productive tied aid*), aid leads to a lower private saving. Consequently, if capital market is closed, productive tied aid leads to a less accumulation of capital which can partially crowd out the positive effect of productive tied aid on the growth of recipient country. However, if capital market is open, private investment is independent from private saving and it depends only on the productivity of the economy. Therefore, for the case of open capital market, the productive tied aid improves the growth through a higher technological progress and, at the same time, through capital inflow.

Most of the findings of this chapter are new in the literature and they imply some policy suggestions to donors. Most importantly, when comparing the aids which are destinated to the low-income European countries (LIEC) and the ones which are designed for poor African countries (PAC), a higher share of aid must be tied to public investment for the former case compared to the latter case. This conclusion is because of the following facts: (i) manufacturing, which is the engine of LBD effect, constitutes a relatively higher share of T-sector in LIEC compared to PAC in which agriculture sector is the main production of the T-sector. (ii) LIEC are relatively more open to international financial market. (iii) The public sector in PAC are more corrupted and it is less likely that donors can force the governments of PAC to use the tied aid efficiently. (iv) Finally, the major needed public investments in PAC are investments in road and water supply which are highly intensive to N-sector. Therefore, the industrialization generated by public investment can be more pronounced for PAC.

Chapter 3

In the last chapter, I study the political economy of the twin deficits and I demonstrate how the centralization of wage bargaining can affect the political incentives of the government to correct or to deteriorate the twin deficits. This chapter contributes to the observed current account imbalances among industrialized economies. Global current account imbalances have been focal points of interest in international macroeconomics, especially since the financial crisis in 2007/2008. Many authors argued that the global imbalances and the global financial crisis are intimately connected (see for example Obstfeld and Rogoff (2009) and Caballero and Krishnamurthy (2009)). The crucial importance of the subject in policy-oriented debates motivated theoretical and empirical researches to identify the fundamental determinants of global current account patterns. The related literature generally find that the saving glut in fast-growing emerging markets and in oil countries as well as financial, institutional and macro variables can, to large extent, account for observed global current account imbalances. According to the existing literature these variables include budget balance, financial development, demographic variables, stage of development, terms of trade volatility and previously accumulated foreign reserves.

This paper provides a new contribution to this literature by studying the relationship between wage centralization and observed current account imbalances among industrial economies. The empirical results of this paper demonstrate that higher wage centralization is significantly and positively associated with current account balances in the cross-section of advanced economies. Besides, the evidence from panel data for 16 OECD countries and over the period 1980-2012 suggests that this link is, to a large extent, through a positive correlation between wage centralization on public savings (budget balance), whereas no evidence is found for the relationship between wage centralization and households savings (the other competent of national saving).

I find robust evidence that wage centralization is associated with higher budget balance in the cross-section of industrial economies. This positive linkage is an important contribution to the literature and to policy-oriented discussions on current account imbalances, given the twin deficits hypothesis. This hypothesis has been studied by a large number of theoretical and empirical papers (see for example Chinn et al. (2014) and Chinn and Ito (2007)). Empirical studies generally suggest that 1% increase in fiscal deficit leads to around $0.1\% - 0.3\%$ increase in current account deficit. The empirical analysis of this paper suggests the magnitude in the same range. This result suggests the existence of a significant but incomplete Ricardian effect. In the aftermath of 2007/2008 financial crisis, many countries faced the challenge of preventing the reemergence of large current account deficits through reducing fiscal deficits. Budget balance is one of the most direct instruments for governments to control external balances (Chinn (2005)). Hence, some crucial questions must be addressed: "why governments in industrial economies behave such differently in managing their fiscal balances and their external debts?" and "What are the determinant factors of budget balance?". This paper tries to shed some light on these questions.

The paper provides a theoretical model to explain the link between the wage centralization and the twin deficits. The mechanism relies on a political economy framework which presumes that the government uses the fiscal balance and its external debt position as a tool for preserving its office.[2] In such a framework, it is assumed that the government, when managing its balance, follows preferences of workers in non-tradeable sector (notably construction and services) who represent the majority in all industrial economies. In all the industrial economies, a large and increasing majority of households are engaged in service and construction sectors. In the US for example, around 67% and 30% of employees were affiliated to the N-sector (construction and service) and T-sector (manufacturing), respectively, in 1960. These numbers changed to 88% and 11% in 2013. The same pattern can be found in other industrial economies. In 2013, the N-sector employment constitute about 88%, 90%, 82% and 78% of total employment in France, UK, Japan and Italy, respectively. Therefore, from a political economy point of view, one can expect that the government in industrial economies is mostly concerned with the impact of its policies on the N-sector workers and pay less attention to the consequences of its policies on the T-sector workers. I argue that wage centralization re-

[2] The role of political incentives, for managing the fiscal balance has been studied by previous literature. See for example Alesina et al. (1998) and Velasco (1999).

duces the N-sector workers' thirst for widening the public external debt and their dismay for public debt reduction. This affects the political incentive of the government in managing its balance. The mechanism which is suggested by the paper is as follows:

A rise in the budget deficit, by issuing external debt, can improve the short-term aggregate welfare through tax reduction and/or increase in public good provision. At the same time, it leads to a surge in inflow of external capital (as long as the Ricardian equivalence fails to be complete). This external capital induces a symptom of Dutch disease: appreciation of real exchange rate, i.e. an increase in the relative price of the N-sector products. Therefore it would be more profitable to produce in the N-sector. Consequently, the surge in the twin deficits induces an inter-sectoral wage dispersion in favor of the N-sector, as friction in the labor market and sector-specific human capital severely constrain the between-sector labor mobility. Correspondingly, workers in the N-sector support more such twin deficits policy compared to workers in the tradeable sector, who are adversely affected by the loss in international competitiveness of their sector and by the decline in their wage (in terms of aggregate price level). For the same reason, the workers in the N-sector relatively opposed more reforms in the twin deficits.

Centralization of wage bargaining decreases this effect by reducing wage flexibility, i.e. the sensitivity of sector-specific wages with respect to sectoral prices (and hence, to changes in real exchange rate). Empirical studies have shown that sectoral wage dispersion, after controlling for labor-skills and job conditions, and the responsiveness of the sectoral wages to sectoral prices is lower in countries with more centralized wage bargaining system (see for example Holmlund and Zetterberg (1991), Hartog et al. (2002) and Teulings and Hartog (1998)). Therefore, the rise (decline) in N-sector (T-sector) wage rates as a response to a positive shock in the twin deficits is lower if the wage is more centralized. Thus, the gains and losses from the twin deficits are smaller. Consequently, wage centralization moderates N-sector workers' supports for the deterioration of the two balances and their oppositions against the reform in the two deficits. Correspondingly, if the wage bargaining is more centralized, the policy maker who follows the preferences of the median voter, finds less political support for widening its external debts and also faces less political costs for improving the two balances.

To the best of my knowledge, this paper is the first attempt to study the relationship between wage centralization and current account. The impact through the budget balance is also new in the literature. Nevertheless, some other links between wage centralization and current account can be deduced by combining the findings of related literature. The most related studies are the ones on inequality-current account relationship. Kumhof et al. (2012), Behringer et al. (2013) and Marzinotto (2016) have shown that in the cross-section of industrial economies, a rise in inequality is associated with an increase in external deficit. This link is explained by the negative impact of inequality on households savings. Given the negative impact of wage centralization on personal income inequality, one can expect that wage centralization can improve the current account via encouraging households savings. Tge empirical results of this paper confirms the chain of these three linkages: inequality-current account, inequality-households savings and wage centralization-inequality. However, no significant evidence is found for a positive impact of wage centralization on households saving. This can be explained by the positive effect of wage centralization on budget balance: the positive impact of wage centralization on public saving tends to reduce the households saving through an incomplete Ricardian effect. This negative impact offsets the positive impact of wage centralization on households savings through reducing inequality.

Chapter 1

Why the rich may want a lower pollution tax? (with Baris Vardar)

Abstract

This work investigates the distributional impacts of a pollution tax by considering a society in which wealth is distributed heterogeneously among households. We present a static general equilibrium model in which firms produce with dirty and/or clean technologies, and show novel results on the effect of a pollution tax on factor prices. When dirty technologies are more capital intensive, pollution tax leads to a reallocation of production factors towards cleaner technology, changing the factor prices in favor of workers. As a result, richer people in the society, who own a larger share of capital, lose a higher proportion of their income compared to the low income households. Consequently, the loss in their well-being due to the fall of income outweighs the benefits of a better environment, and their support for a pollution tax declines. These results propose a theoretical explanation for the question of why the rich may prefer a low pollution tax.

Keywords: heterogeneity in wealth, environmental policy, pollution tax, distributional impacts, firm behavior, household behavior, sources side.

JEL-Classification: H23, Q52, Q58

1.1 Introduction

Who is willing to give more support for environmental protection? And what are the sources of differences among households that lead them to prefer different levels for environmental policy tools such as pollution taxes? In this study, we focus on these questions and particularly on the dimension of heterogeneity in wealth and its implications on the preferred pollution tax of the households. Environmental policies may affect the households with a higher wealth differently than the ones with a lower wealth because of the fact that they have more capital invested in the market and because their consumption levels are not the same.[1] Given these differences, we address the question that may the richer people in society prefer a lower pollution tax than the poorer ones? We address this question by focusing on the impact of pollution tax on factor prices and households' revenue.

Firms' demands for production factors can be affected by the policies that aim to reduce the level of pollution if firms/industries with different polluting levels have different intensities to production factors. Therefore these policies can have important impacts on the factor prices such as the wage and the interest rate. In a general equilibrium setting, changes in factor prices affect the household revenues. Indeed, when factors are unevenly distributed within the society, these impacts can lead to differences in the preferred pollution taxes of households.

There has been a few works, mainly empirical, that study the distributional impacts of environmental policies. Most of the studies consider a partial equilibrium framework by focusing only on the uses side of income, which means the impact of environmental policies on the

[1]Throughout the text we treat capital ownership and wealth as identical terms. This equivalence relies on the assumption that all wealth owned by the households are lent to the firms in the economy and thus employed in production.

commodity prices. The common result is that pollution taxes are regressive because the dirty commodities constitute a larger share of the poor households' expenditures. Besides, there is a growing literature that consider a general equilibrium framework and thus taking into account the sources side of income as well. This literature are closer to our framework. For example, Fullerton and Heutel (2007) study the incidence of environmental taxes in a general equilibrium framework and they take into account general forms of substitution among the factors. They show the importance of elasticity of substitution between dirty and clean goods in both production and consumption sides. Furthermore, using this framework, they identify the impact of a pollution tax on the factor prices as well as on the prices of the final goods. In more recent works, Rausch et al. (2011) and Dissou and Siddiqui (2014), by using a similar approach, show that the pollution tax can be progressive by considering the sources side of income.

The incidence of environmental taxes can also be studied by considering the heterogeneities among the households in terms of labor income, transfer income or time preferences. For example, Chiroleu-Assouline and Fodha (2014), Fullerton and Monti (2013) and Marsiliani and Rengstrom (2002) study the heterogeneity in terms of labor income, Fullerton and Heutel (2010) and Rausch et al. (2011) study the heterogeneity in terms of transfer income and Borissov et al. (2014) could be given as an example that study the heterogeneity in the discount rates of the households. In this paper we abstract from these and we consider only the case of heterogeneity in terms of capital endowment. Study on this dimension of heterogeneity has been absent in the literature even though it can have crucial importance in policy-oriented debates.

The income data of the U.S. economy from the 2007 Survey of Consumer Finances (SCF) show that the revenues from capital constitute 25% of the total overall income. Moreover, as shown by Fullerton and Heutel (2010), the fraction of income coming from capital is increasing over income deciles.[2] For example, the fraction of income that comes from capital is 5.7% for the lowest income decile, 7.8% for the fifth income decile and 45.6% for the highest income decile. Accordingly, neglecting the heterogeneity in capital revenues generates a significant gap in the theoretical analysis.

In a recent empirical study, by using micro data from European Value Survey (EVS), Ercolano et al. (2014) show an inverted U-shaped relationship between income of the households and their willingness to monetary contribution to protection of the environment. This means that for households in the low and middle income deciles, the higher income is associated with higher willingness to pay for a better environment. However, for the highest income percentiles, the willingness to pay for environmental protection decreases with the income. What distinguishes the highest percentile income households from the others is the fact that the share of income coming from wealth, as well as heterogeneity in wealth, is more pronounced for them, as shown in data from the SCF. The combination of these two observations makes us to question if heterogeneity in wealth is a determinant factor to explain the negative relationship between income and support for pollution taxes among the very high percentile income households. To the best of our knowledge there is no theoretical paper to explain this observation. Our theoretical results provide one possible explanation for negative relationship between households' income and the support for environmental protection in top percentiles.

[2]With the exception that the lowest income decile has slightly higher share of capital in their income compared to the next decile.

Heterogeneity in wealth is taken into account in few previous studies. For example, Rausch et al. (2011) and Dissou and Siddiqui (2014) consider it but they do not conduct in depth theoretical analysis its implications on the households' support for environmental protection. Furthermore, Kempf and Rossignol (2007) study the relationship between wealth inequality and environmental protection in a theoretical framework and address the questions that are similar to ours. By using an endogenous growth model, they show that the richer households prefer a higher environmental tax and correspondingly inequality is harmful for the environment. But this result is based on the fact that the relative price of labor to capital is independent from the environmental tax since their model does not incorporate alternative cleaner production technologies. This dimension is indeed the main focus of our paper and it makes our framework, and thus our results, significantly different from theirs.

Our aim in this study is two folds. First, to investigate the effects of a pollution tax on the firm behavior and factor prices in the partial competitive equilibrium and to identify the determinants of these effects. Second, in a general equilibrium setting, to relate these findings to households' preferred pollution taxes and eventually to identify the cases in which the pollution tax is regressive or progressive in terms of households' welfare.[3] As we explain in the following paragraphs, some of our results about the impact of pollution tax on factor prices are new in the literature.

We develop a static general equilibrium model by taking into account households, firms and the government. Households have different wealth endowments and their utility depends on their consumption

[3]In this paper, we use the progressivity and regressivity terms always in terms of welfare.

level and the level of environmental quality. The level of environmental quality depends negatively on the level of pollution. The production side of the model is inspired by the works of Harberger (1962), Copeland and Taylor (2004), Fullerton and Heutel (2007) and many others that apply the international trade framework of Heckscher-Ohlin. We study an economy with firms that produce a generic good by using two different technologies, namely dirty and clean, with each of them using capital, labor and pollution as an input to produce the final output.[4] The factor prices of capital and labor are determined endogenously in the equilibrium, the government determines the pollution tax and uses its revenues for government spending purposes.

Our results show that the impact of a pollution tax on the factor prices depends on the characteristics of the production technologies utilized by the firms in the economy. Following the empirical results in the previous literature, we consider that the dirty technology is more capital intensive than the clean one. In this cse, the interest rate always decreases with the pollution tax. But, whether the wage increases or decreases depends on the comparison of the relative intensities of pollution and capital between the production technologies. In particular, we show that the wage increases when the relative pollution intensity respect to capital is higher in the dirty technology, and *vice versa*. These results, which we summarize in Table (1.1), differ from the many studies in the literature (for example Copeland and Taylor (2004), Fullerton and Heutel (2007)). These findings are based on the fact that in our setting, contrary to theirs, the clean technology also pollutes thus its pollution intensity matters.

[4]The use of pollution as an input in the production process is a well-established modeling approach in the environmental economics literature and the motivation behind is explained in Section 2.1.

On the household side, we investigate the household's decision about its preferred pollution tax and we identify the trade-off that they face between a higher consumption and a better environmental quality. At this point, this paper differs from the ones in the literature (such as Fullerton and Heutel (2007), Dissou and Siddiqui (2014) in two ways. First, we consider the utility of household depends also on the environmental quality that leads to the trade-off that we mentioned above. Second, this paper does not address the uses side effects of the pollution tax. The reason is that our model constitute a closed economy in which the firms produce a generic good by using alternative technologies.[5] In this setting, pollution tax has no effect on the commodity prices. On the contrary, the models presented by those papers are consistent with a closed economy with two sectors. Therefore, the pollution tax increases the relative price of the dirty good to the clean one and thus causes the uses side effect.

Having only the sources side in the setting leads us to find the effect of wealth on a household's preferred pollution tax which depends on two opposite channels. We call the first one as the *satiation effect*. It says that households with a higher wealth consume more and their marginal utility of consumption is lower, thus they would be more willing to sacrifice from their consumption for a better environmental quality. And we call the second channel as the *income burden effect*. It says that households with a higher wealth have larger capital investments in the market, thus, when the return of capital falls their revenues are more reduced by the pollution tax. Accordingly, whether

[5]Our model can also be interpreted as a small open economy with two sectors in which the production factors are mobile across sectors but immobile across countries. In this type of setting, the country engages in goods trade but has an isolated financial market. This setting is suitable for some of the developing countries today.

the pollution tax increases or decreases with wealth depends on which one of these effects dominates. We show that, in fact, it depends on the pollution tax elasticity of consumption that is determined by the pollution tax elasticities of the factor prices.

By using these results, in the general equilibrium, we show that if the firms are operating with a single production technology then the richer households prefer a higher pollution tax, hence the tax is regressive. On the contrary, if the firms are using the dirty and clean technologies simultaneously, the pollution tax leads to a reallocation of resources in the clean technology. In this case, when the dirty technology is more capital intensive, the richer households lose more from their consumption in percentage terms which means that they would prefer a lower pollution tax. In other words, when the economy operates on two technologies the tax is progressive.

The following section presents the model. Section 3 presents the firm decision and analyzes the impact of a pollution tax on the factor prices, Section 4 explains the role of the government and how the proceeds from the pollution tax are used, Section 5 presents the household decision, Section 6 characterizes the general equilibrium for this economy and Section 7 shows the conditions for the impact of the wealth on the preferred pollution tax of an household. Then Section 8 discusses the implications of the cases when some of the assumptions that we made are relaxed. Finally Section 9 concludes.

1.2 The framework

Within a static framework, we analyze a closed economy that consists of households, firms and the government. We consider a continuum of households indexed by $i \in (0, 1)$ with each of them supplying one unit of labor inelastically. Each household i has an initial capital (*wealth*) endowment k_i, and he total capital in the economy is $\bar{K} = \int_0^1 k_i di$.

Household's utility $V(c, E)$ depends on consumption of the generic good (c) and the level of environmental quality (E) that decreases with the level of pollution (z). The firms produce the generic good in a perfectly competitive market by using capital (k), labor (l) and pollution. The factor prices of capital and labor (r and w) are determined endogenously in the equilibrium. The government determines the unit price of pollution (τ) and uses the collected tax revenue for its expenditures.

In the following sections we explain the aims and the decision making processes of the firms, the government and the households in detail and study the outcome in a general equilibrium framework.

1.3 Production

The production of the generic good is a function of capital (k), labor (l) and pollution (z). We consider the price of the generic good as numeraire. In line with Siebert et al. (1980), Copeland and Taylor (1994), Copeland and Taylor (2004), Fullerton and Heutel (2007), we take into account pollution as an input in the production process. This approach for modeling production is usually called as "joint production technology".

One way of motivating this is to think about two production processes: the first one is the production of the final good and the second one is the abatement of pollution. The first production process uses capital and labor as inputs and produces the final good as well as pollution as a by-product. The second one also employs capital and labor to produce equipment which are used to reduce the level of pollution that is generated by the first production process. These two production processes can be transformed into a joint production technology, which is depicted in figure 1.1. Jouvet et al. (2005) also shows a similar exercise of this transformation and conclude by obtaining a production function homogenous of degree one of capital, labor and pollution.

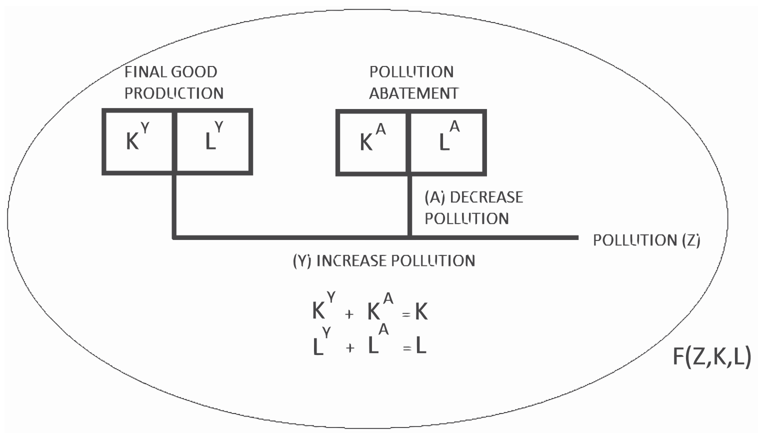


Figure 1.1: Joint production technology

We assume functional separability between pollution and the physical inputs in the joint production technology. Hence, the production function is denoted as $F(z, G(k, l))$ where the first argument of $F(., .)$ is pollution (z) and the second argument is the conjoint physical input of capital and labor $(G(k, l))$. This way of specification is similar to and more general than the one in Copeland and Taylor (2004).[6] Functional separation implicitly assumes that the relative factor demands are identical in both final good production process and the pollution

[6]Copeland and Taylor (2004) assumes that the production function is Cobb-Douglas in pollution and conjoint physical input of capital and labor, that is $x = z^{\alpha}(F(K_x, L_x))^{1-\alpha}$.

abatement process. [7] As will be shown later on, this restriction is necessary to analyze the single production technology (Section 2.1.1) while it is not necessary for multiple production technologies (Section 2.1.2). We prefer to keep this form to maintain consistency throughout the text.

This nested structure for production function captures the fact that the physical inputs for production (capital and labor) are having a bilateral elasticity of substitution between them and pollute to operate the production process. Moreover, the conjoint physical input of capital and labor has an elasticity of substitution with pollution. The shapes of $F(.,.)$ and $G(.,.)$ determines the substitutability (or complementarity) of each input respect to the others. We assume the following properties for the production function:

Assumption 1. *The production function satisfies the following properties:*[8,9]

(i) $F(.,.)$ *and* $G(.,.)$ *are homogenous of degree one.*

(ii) $F_1(.,.) > 0,\ F_{11}(.,.) < 0,\ F_2(.,.) > 0,\ F_{22}(.,.) < 0,\ F_{12}(.,.) > 0$

(iii) $G_1(.,.) > 0,\ G_{11}(.,.) < 0,\ G_2(.,.) > 0,\ G_{22}(.,.) < 0,\ G_{12}(.,.) > 0$

Assumption 1 means that the production technology embodies con-

[7] See Appendix 1.9 for details. Note that this certain assumption is necessary just for this motivation of the production function and it does not have any role in our results.

[8] Throughout the text we use the following notations for a derivative of a function: $f'(x) = \partial f/\partial x$, $f''(x) = \partial^2 f/\partial x^2$, $f_i(x,y) = \partial f/\partial i$ and $f_{ij}(x,y) = \partial^2 f/\partial i \partial j$ where i and j denote the order of the arguments of f. For example, $f_1(x,y) = \partial f/\partial x$, $f_2(x,y) = \partial f/\partial y$, $f_{11}(x,y) = \partial^2 f/\partial x^2$ and $f_{12}(x,y) = \partial^2 f/\partial x \partial y$.

[9] These assumptions on the production function are satisfied by most commonly used production functions such as Cobb-Douglas and CES. We consider to proceed on the analysis by using the general form in order to cover a larger family of functional forms.

stant returns to scale. It also implies that each factor's marginal productivity is positive and decreasing in its amount and is increasing in other factors' amounts. [10]

We proceed step by step for the decision making process of the firms. Our aim is to analyze the effect of a change in the pollution tax on the prices of capital and labor and on the allocation of resources in the economy. We first investigate a simple case in which there is only a single production technology available. Then we study the case in which there are two alternative production technologies with different factor intensities. We will show that these two cases may have contrasting results depending on the characteristics of the production technologies.

1.3.1 Single production technology

In this framework there is only one production technology available. The firms take the prices of input factors as given and minimize their cost by deciding on their factor demands $(\alpha_z, \alpha_k, \alpha_l)$ for producing one

[10]The assumptions on capital and labor are straightforward and standard, however, the ones on pollution still need to be justified. Total output increases if we increase pollution keeping the amount of capital and labor constant ($F_1(.,.) > 0$). One can think that in this case the amount of capital and labor allocated for abatement activities are reallocated in the production of the final good. Therefore pollution will increase due to decreased abatement and total output will increase due to higher amount of capital and labor employed in the final good production process. Of course a technology is more *dirty* if it needs more amount of capital and labor relocated from final good production to the pollution abatement for having a unitary decrease in pollution.

unit of the output. The problem of the representative firm is:

$$\min_{\{\alpha_z,\alpha_k,\alpha_l\}} \{\tau\alpha_z + r\alpha_k + w\alpha_l\} \tag{1.1}$$

$$\text{subject to } F(\alpha_z, G(\alpha_k, \alpha_l)) = 1 \tag{1.2}$$

$$\text{and } 0 \leq \alpha_j \text{ for } j \in \{z, k, l\}$$

where r, w and τ denote the interest rate, wage and unit pollution tax respectively. The cost minimization problem in (1.1) yields the following first order conditions:

$$F_1(\alpha_z, G(\alpha_k, \alpha_l)) = \tau \tag{1.3}$$

$$F_2(\alpha_z, G(\alpha_k, \alpha_l))G_1(\alpha_k, \alpha_l) = r \tag{1.4}$$

$$F_2(\alpha_z, G(\alpha_k, \alpha_l))G_2(\alpha_k, \alpha_l) = w \tag{1.5}$$

Since marginal productivity of each factor is always positive and we assume perfect competition among the firms, capital and labor will be employed at their highest quantities ($\bar{K}$ and $\bar{L}$) in the equilibrium. Constant returns to scale property of the production function implies that the relative intensity of capital to labor is fixed by the factor endowment in the economy.

$$\frac{\alpha_k}{\alpha_l} = \frac{\bar{K}}{\bar{L}} \tag{1.6}$$

Equations (1.2 to 1.6) allow us to obtain factor intensities and the prices of capital and labor as a function of the pollution tax ($\alpha_z(\tau)$, $\alpha_k(\tau), \alpha_l(\tau), w(\tau), r(\tau)$). Furthermore, by taking into account the fact that $\bar{K} = \alpha_k(\tau)F\Big(\alpha_z(\tau), G(\alpha_k(\tau), \alpha_l(\tau))\Big)$ or $\bar{L} = \alpha_l(\tau)F\Big(\alpha_z(\tau), G(\alpha_k(\tau)$ $\alpha_l(\tau))\Big)$ we can determine the equilibrium level of output.

In the equilibrium, an increase in pollution tax decreases the pollution intensity of production ($\alpha_z'(\tau) < 0$). A lower pollution intensity reduces the marginal productivity (and hence the price) of conjoint physical input ($F_2(., G(.))$). Moreover, the relative price of capital and labor will not change since the relative intensity of capital to labor is fixed by the total endowment (eq. (1.6)). As a result, the prices of labor and capital will decrease at the same rate.

Proposition 1. *When firms operate by using a single production technology, in the partial equilibrium, the wage and the interest rate are decreasing in the pollution tax ($w'(\tau) < 0$, $r'(\tau) < 0$). Moreover, both has the same elasticity respect to the pollution tax, $\epsilon_{w,\tau} = \epsilon_{r,\tau} < \epsilon_{R,\tau} < 0$.*[11] *where R denotes the gross interest rate.*[12]

Proof. See Appendix 1.9. □

To summarize, in this basic framework the interest rate and the wage decreases with the same elasticity as a response to an increase in the pollution tax. This result relies on the following assumptions: (i) only one technology is available in the economy, (ii) the production function is constant returns to scale and it is separable between pollution and conjoint physical input of capital and labor, (iii) the endowment of capital and labor is fixed in the economy, (iv) labor supply is inelastic.

In the following subsection, we will relax the first assumption and we investigate how the results will change. More specifically, we will investigate how the responses of factor prices to an increase in pollution

[11] The term $\epsilon_{x,y}$ denotes the elasticity of x respect to y ($\frac{\partial x/\partial y}{x/y}$)

[12] Here we also report the differences respect to the elasticity of gross capital return because they will be useful for the analysis of the household's problem.

tax will change when an alternative production technology is available to use.

1.3.2 Two production technologies: dirty and clean

In this framework, we consider that the generic good can be produced by using two different technologies: dirty (X) and clean (Y).[13] The two technologies both require the use of capital (k), labor (l) and pollution (z) and they are denoted as $X = F^X(z_x, G^X(k_x, l_x))$ and $Y = F^Y(z_y, G^Y(k_y, l_y))$. The functions $F^i(.)$ and $G^i(.)$ for $i \in \{X, Y\}$ satisfy the properties given in Assumption 1.

The representative firm takes the factor prices as given and minimizes its unit cost of production for each technology with the following programme:

$$\min_{\left\{\alpha_z^X, \alpha_k^X, \alpha_l^X, \alpha_z^Y, \alpha_k^Y, \alpha_l^Y\right\}} \left\{\tau(\alpha_z^X + \alpha_z^Y) + r(\alpha_k^X + \alpha_k^Y) + w(\alpha_l^X + \alpha_l^Y)\right\} \tag{1.7}$$

$$\text{subject to } F^i(\alpha_z^i, G^i(\alpha_k^i, \alpha_l^i)) = 1 \text{ for } i \in \{X, Y\} \tag{1.8}$$

$$\text{and } 0 \leq \alpha_j^i \text{ for } i \in \{X, Y\} \text{ and } j \in \{z, k, l\}$$

The cost minimization problem leads to the following first order conditions:

[13] Studying only two technologies case is not too restrictive because even if we had taken into account an economy with n technologies, in this framework, the firms would utilize maximum two of them. This assertion is valid in the case where $F^i(.)$ and $G^i(.)$ for $i \in \{1, ..., n\}$ are homogenous of degree one. See appendix D for details.

$$F_1^X(\alpha_z^X, G^X(\alpha_k^X, \alpha_l^X)) = F_1^Y(\alpha_z^Y, G^Y(\alpha_k^Y, \alpha_l^Y)) = \tau \quad (1.9)$$

$$F_2^X(\alpha_z^X, G^X(\alpha_k^X, \alpha_l^X))G_1^X(\alpha_k^X, \alpha_l^X) = F_2^Y(\alpha_z^Y, G^Y(\alpha_k^Y, \alpha_l^Y))G_1^Y(\alpha_k^Y, \alpha_l^Y) = r \quad (1.10)$$

$$F_2^X(\alpha_z^X, G^X(\alpha_k^X, \alpha_l^X))G_2^X(\alpha_k^X, \alpha_l^X) = F_2^Y(\alpha_z^Y, G^Y(\alpha_k^Y, \alpha_l^Y))G_2^Y(\alpha_k^Y, \alpha_l^Y) = w \quad (1.11)$$

where $\{\alpha_z^i, \alpha_k^i, \alpha_l^i\}$ for $i \in \{X, Y\}$ are the derived demands of pollution, capital and labor, respectively, for producing one unit of output by using technology i. The six first order equations in (1.9 - 1.11) allow us to obtain the unit factor demands as a function of the factor prices: $\{\alpha_z^i(r, w, \tau), \alpha_k^i(r, w, \tau),\ \ \alpha_l^i(r, w, \tau)\}$. In fact, when we consider profit maximization problem which is the dual of problem (1.7), we have the same first order conditions and the same functions for factor demands. Substituting the factor demands into the iso-unit cost function leads to an implicit relationship between the factor prices such that $C(r, w, \tau) = 1$. This implicit relationship is the factor price frontier. Indeed, it corresponds to the minimum value of the cost in (1.7) under all technical conditions including the constraint of one unit of production given in (1.8). In the following, we show that at least one factor price (w and/or r) decreases as a response to an increase in the pollution tax. That is consistent with the factor price frontier.

Replacing the factor demands we obtained before ($\{\alpha_z^i(r, w, \tau),$ $\alpha_k^i(r, w, \tau), \alpha_l^i(r, w, \tau)\}$) into the two equations in (1.8), we can find wage and interest rate as a function of pollution tax ($w(\tau), r(\tau)$).

Hence, we find the intensities of all factors in each sector and prices of capital and labor as a function of pollution tax. Note that contrary to the single technology framework, factor intensities, wage and interest rate are independent from the total resource endowment ($\bar{K}$ and $\bar{L}$).

We define the technology with higher pollution intensity as the dirty one and we assume no factor intensity reversal to ensure that the dirty technology, according to this definition, always remains as the dirty one. Moreover, we assume that the dirty technology is more capital intensive as well. This assumption is based on the previous empirical findings. For example, recently, Fullerton and Heutel (2010) calculated the factor intensities of the US economy in clean and dirty sectors, in which they defined petroleum refining, electricity and transportation industries as the dirty sector, and all remaining industries as the clean one. They showed that relative intensity of capital with respect to labor in dirty industries is $\frac{\alpha_k^X(\tau)}{\alpha_l^X(\tau)} = 1.28$ whereas the same indicator for the clean industries is $\frac{\alpha_k^Y(\tau)}{\alpha_l^Y(\tau)} = 0.60$. Hettige et al. (1995) find Petroleum, Primary metals, Paper and Chemical industries as the most polluting industries in the US. These industries are also ranked as the most capital intensive industries in the US (see Cole and Elliott (2005)). Cole and Elliott (2005) also find that there is significant and positive correlation of 0.69 (t-statistics of 4.1) and 0.53 (t-statistics of 6.8) between pollution intensity and capital intensity in the US industries at the two- and three-digit levels (123 industries), respectively.[14] Cole and Elliott (2003) using panel data analysis find robust and positive correlation between capital intensity and emissions of the

[14] In this study, Cole and Elliott (2005) measure the pollution intensity as pollution abatement cost as a percentage of GDP and capital intensity as physical capital intensity per worker. Their work show that there is the correlation of 0.67 (t-statistics of 9.6) between the two variables when pollution intensity is measured in per worker terms.

most pollutants (measured as percentage of values added) which are by-product from good productions.[15]

Formally, we assume the following:

Assumption 2. *The dirty technology (X) is assumed to be more capital intensive than the clean technology (Y):*

$$\alpha_z^X(\tau) > \alpha_z^Y(\tau), \qquad \alpha_k^X(\tau) > \alpha_k^Y(\tau) \qquad \alpha_l^X(\tau) < \alpha_l^Y(\tau).$$

Note that in Assumption 2 we compare the factor intensities ($\frac{z_x}{X} > \frac{z_y}{Y}, \frac{k_x}{X} > \frac{k_y}{Y}, \frac{l_x}{X} < \frac{l_y}{Y}$) between the technologies to define the type of production technology. This approach is equivalent to the comparison of factor shares in production ($\frac{\tau z_x}{X} > \frac{\tau z_y}{Y}, \frac{rk_x}{X} > \frac{rk_y}{Y}, \frac{wl_x}{X} < \frac{wl_y}{Y}$).

As we stated before, the factor intensities and the factor prices are independent from the aggregate level of capital and labor. However, the allocation of resources between the two technologies will depend on the total resources. The total demand for factor j in technology a can be computed by multiplying the unit demand for that factor and the total production of that technology. Therefore, the total resource constraint implies the following:

$$X\alpha_k^X(\tau) + Y\alpha_k^Y(\tau) = \bar{K} \tag{1.12}$$

$$X\alpha_l^X(\tau) + Y\alpha_l^Y(\tau) = \bar{L} \tag{1.13}$$

where X and Y represent total production by the dirty and clean technology respectively. Solving these two equations for total output

[15]The pollutant in that study include sulfur dioxide, Nitrogen oxides, carbon dioxide and BOD.

of each technology (X and Y) yields to the following relations:

$$F^X(z_x, G^X(k_x, l_x)) = X(\tau) = \frac{\alpha_l^Y(\tau)\bar{K} - \alpha_k^Y(\tau)\bar{L}}{\alpha_k^X(\tau)\alpha_l^Y(\tau) - \alpha_l^X(\tau)\alpha_k^Y(\tau)} \tag{1.14}$$

$$F^Y(z_y, G^Y(k_y, l_y)) = Y(\tau) = \frac{\alpha_l^X(\tau)\bar{K} - \alpha_k^X(\tau)\bar{L}}{\alpha_k^Y(\tau)\alpha_l^X(\tau) - \alpha_l^Y(\tau)\alpha_k^X(\tau)} \tag{1.15}$$

Using equations (1.14) and (1.15) we can obtain the allocation of each factor between the technologies, that is, $z_x(\tau) = X(\tau)\alpha_z^X(\tau)$, $k_x(\tau) = X(\tau)\alpha_k^X(\tau)$, $l_x(\tau) = X(\tau)\alpha_l^X(\tau)$, $z_y(\tau) = Y(\tau)x_y(\tau)$, $k_y(\tau) = Y(\tau)\alpha_k^Y(\tau)$, $l_y(\tau) = Y(\tau)\alpha_l^Y(\tau)$.

Now that we obtained all the factor intensities, the factor prices, the amounts of each factor employed in each technology and the total amounts of production made by using each technology, we can characterize the partial competitive equilibrium:

Definition 1. *For a given pollution tax (τ), the unique partial competitive equilibrium for this economy is characterized by the vector of factor intensities in each technology $\{\alpha_z^X, \alpha_k^X, \alpha_l^X, \alpha_z^Y, \alpha_k^Y, \alpha_l^Y\}$, the vector of labor and capital prices $\{w, r\}$, the vector of the factors amounts employed in each technology $\{z_x, k_x, l_x, z_y, k_y, l_y\}$ and the the total production in each technology $\{X, Y\}$ such that:*

- *The firms minimize their costs, thus (1.8 to 1.11) hold.*
- *The markets clear, thus the resource constraints ((1.14 and 1.15)) hold.*

By using the definition above, we determine the level of total output and allocation of factors between the two technologies, as well as the factor intensities and the factor prices at the equilibrium as a function of the pollution tax. So how does the pollution tax affects these variables, in particular the prices of capital and labor?

An increase in the pollution tax makes pollution more expensive as an input. Hence both sectors will use pollution less intensively which causes an adverse effect on the productivities of labor and capital. Since the dirty technology is more pollution intensive, an increase in the tax affects the use of this technology at most. It will be more profitable for the firms to use the clean technology, thus, some of the resources that are used in the dirty technology will be reallocated in the clean one. Consequently, the share of the clean technology, which is more labor intensive, will increase in aggregate production. This leads to an increase in relative productivity of labor respect to capital.

Accordingly, a rise in the pollution tax affects the factor prices from two channels: (*i*) a decline in pollution intensity and (*ii*) reallocation of capital and labor from the dirty technology to the clean one. Both channels impose a negative impact on the interest rate while they push the wage in two opposite directions. On the one hand, less pollution intensity pushes the wage downward, and on the other hand, factor reallocation from capital intensive technology to the labor intensive one pushes it upward. Whether the wage increases or decreases depends on which one of these effects dominates.

In the following proposition we show that in fact it depends on the relative intensity of pollution and capital between the two technologies:

Proposition 2. *When the economy operates using both technologies, the interest rate decreases in the pollution tax ($r'(\tau) < 0$). However, the change in the wage ($w'(\tau) \lesseqgtr 0$) depends on the technologies' relative* *pollution intensities respect to capital.*

(i) *if* $\dfrac{\alpha_z^X}{\alpha_k^X} < \dfrac{\alpha_z^Y}{\alpha_k^Y}$ *then* $r'(\tau) < 0, w'(\tau) < 0$ *and* $\epsilon_{r,\tau} < \epsilon_{R,\tau} < \epsilon_{w,\tau} < 0$

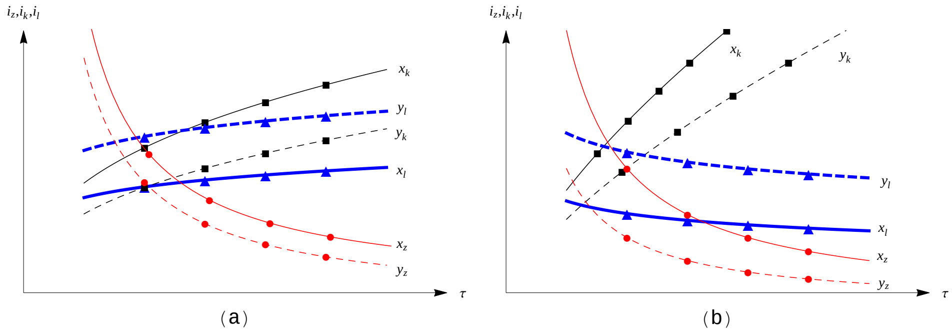
(ii) *if* $\dfrac{\alpha_z^X}{\alpha_k^X} = \dfrac{\alpha_z^Y}{\alpha_k^Y}$ *then* $r'(\tau) < 0, w'(\tau) = 0$ *and* $\epsilon_{r,\tau} < \epsilon_{R,\tau} < \epsilon_{w,\tau} = 0$

(iii) *if* $\dfrac{\alpha_z^X}{\alpha_k^X} > \dfrac{\alpha_z^Y}{\alpha_k^Y}$ *then* $r'(\tau) < 0, w'(\tau) > 0$ *and* $\epsilon_{r,\tau} < \epsilon_{R,\tau} < 0 < \epsilon_{w,\tau}$

Proof. See Appendix 1.9. □

The comparison of the two cases ((i) and (iii)) in Proposition 2 is illustrated in fig.(2.1). As it is clear from the figure, pollution will be used less intensively in both technologies when the pollution tax increases. Besides, as Proposition 2 asserts, the interest rate declines in both cases as a response to an increase in the pollution tax. This makes firms to use capital more intensively in both technologies. However, the wage can increase or decrease once the pollution tax rises. When the relative pollution intensity of the dirty technology to the clean one $(\frac{\alpha_z^X}{\alpha_z^Y})$ is lower than the relative capital intensity $(\frac{\alpha_k^X}{\alpha_k^Y})$ then the wage decreases and so labor is employed more intensively in both technologies. (fig.(2.1,a)). In the contrary case $(\frac{\alpha_z^X}{\alpha_z^Y}) > (\frac{\alpha_k^X}{\alpha_k^Y})$, higher pollution tax leads to an increase in the wage, therefore more environmental protection leads to a decline in labor intensities of both technologies. fig.(2.1,b).

Whether the relative intensity of capital to labor increases or decreases in the two technologies depends on how their relative price changes with the pollution tax. Proposition 2 implies that the relative price of capital to labor will decrease as a response to higher pollution tax. Therefore, more environmental protection makes the firms to use capital more intensively. This leads us to the following proposition:



Note: Panel (a) illustrates the case where $\frac{\alpha_z^X}{\alpha_k^X} < \frac{\alpha_z^Y}{\alpha_k^Y}$ and panel (b) illustrates the case where $\frac{\alpha_z^X}{\alpha_k^X} > \frac{\alpha_z^Y}{\alpha_k^Y}$. The solid curves are for the dirty technology (X) and the dashed curves are for the clean one (Y). The squares, triangles and circles mark the unit factor demand curves for capital, labor and pollution respectively.

Figure 1.2: Example unit factor demands respect to the pollution tax

Proposition 3. *If the economy operates using both technologies, and if Assumption 1 and Assumption 2 hold, then higher pollution tax will increase relative intensity of capital to labor in both technologies.*

$$\frac{d(\alpha_k^i(\tau)/\alpha_l^i(\tau))}{d\tau} > 0 \qquad \textit{for } i \in \{X, Y\} \tag{1.16}$$

where, α_j^i is the unit-demand for factor j in technology i.

Proof. See Appendix 1.9.

□

As it can be seen in Appendix 1.9, functional separability between pollution and physical inputs is not necessary for Proposition 2. But, Proposition 3 is conditional on that assumption.

Proposition 3 implies two extreme cases: In one extreme case, when the pollution tax is sufficiently high, all the resources will be allocated only in the clean technology and at this point capital/labor ratio in the clean technology equals to the ratio between total capital and total labor in the economy. As the tax decreases, the resources will be reallocated in the dirty technology and both technologies will become more labor intensive. In the other extreme case, the tax will be low enough such that all resources will be allocated only in the dirty technology. Obviously, in this case the capital/labor ratio in the dirty technology equals to the ratio of their total endowments in the economy.

Accordingly, we can define two thresholds for the pollution tax: *(i)* the dirty threshold and *(ii)* the clean threshold. In the case where the pollution tax is lower than the dirty threshold only the dirty technology is used and if it is greater than the clean threshold the firms operate by using only the clean technology. When the tax is between these thresholds, the firms will operate by using both of the technologies simultaneously in production.

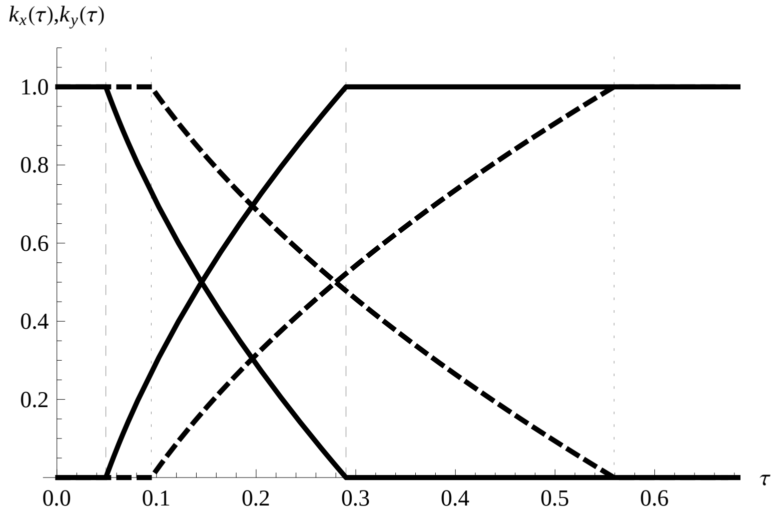
Proposition 4. *If* τ_{dirty} *and* τ_{clean} *satisfy* $\frac{\alpha_k^X(\tau_{dirty})}{\alpha_l^X(\tau_{dirty})} = \frac{\bar{K}}{\bar{L}}$ *and* $\frac{\alpha_k^Y(\tau_{clean})}{\alpha_l^Y(\tau_{clean})} = \frac{\bar{K}}{\bar{L}}$*, then:*

(i) *if* $\tau \leq \tau_{dirty}$ *then firms use only dirty technology,* $k_x = \bar{K}, l_x = \bar{L}$
$k_y = 0, l_y = 0.$
(ii) *if* $\tau_{dirty} < \tau < \tau_{clean}$ *then firms use dirty and clean technologies simultaneously* $k_x > 0, l_x > 0, k_y > 0, l_y > 0$ *with* $k_x + k_y = \bar{K}, l_x + l_y$
$= \bar{L}.$
(iii) *if* $\tau \geq \tau_{clean}$ *then firms use only clean technology,* $k_x = 0, l_x = 0,$
$k_y = \bar{K}, l_y = \bar{L}.$

Proof. See Appendix 1.9.

∎

As it is shown in Proposition 4, τ_{dirty} and τ_{clean} depend only on



Note: The solid lines are for $\bar{K}/\bar{L} = 0.5$, the dashed lines are for $\bar{K}/\bar{L} = 0.7$.

Figure 1.3: Illustration of Proposition 4

the relative endowment of capital and labor in the economy. Using the definition of these thresholds and equation (1.16), we can show that both of the thresholds are increasing in $\frac{\bar{K}}{\bar{L}}$. For a given amount of labor force, the more capital endowed in the economy is, the more profitable the dirty technology would be compared to the clean one. Therefore, it would require a higher pollution tax to induce the firms to use the cleaner technology. This is illustrated in figure 1.3. The following corollary presents this result.

Corollary 1. *τ_{dirty} and τ_{clean} are both increasing in the ratio of total capital and labor in the economy, $\partial\tau_{dirty}/\partial(\bar{K}/\bar{L}) > 0$ and $\partial\tau_{clean}/\partial(\bar{K}/\bar{L}) > 0$.*

Proof. See See Appendix 1.9.

□

Table (1.1) summarizes the results of Proposition 1 and Proposition

2 that show the impact of an increase in the pollution tax on the prices of capital and labor.

	Single technology	Dirty&clean technologies	
		$\alpha_z^X/\alpha_k^X < \alpha_z^Y/\alpha_k^Y$	$\alpha_z^X/\alpha_k^X > \alpha_z^Y/\alpha_k^Y$
Interest rate	$r'(\tau) < 0$	$r'(\tau) < 0$	$r'(\tau) < 0$
Wage	$w'(\tau) < 0$	$w'(\tau) < 0$	$w'(\tau) > 0$
Elasticities	$\epsilon_{r,\tau} = \epsilon_{w,\tau} < \epsilon_{R,\tau} < 0$	$\epsilon_{r,\tau} < \epsilon_{R,\tau} < \epsilon_{w,\tau} < 0$	$\epsilon_{r,\tau} < \epsilon_{R,\tau} < 0 < \epsilon_{w,\tau}$

Table 1.1: Impact of an increase in pollution tax on factor prices and their tax elasticities

We can conclude the analysis of production side by stating that the effects of an increase in the pollution tax on factor prices depend on the characteristics of the production technologies available and utilized by the firms in the economy. When the production technologies satisfy the properties given in Assumption 1 and Assumption 2, meaning that the technologies embody constant returns to scale and the dirty technology is more capital intensive than the clean one, the impact of an increase in the pollution tax on the factor prices will be as shown in Table (1.1) in the equilibrium.

1.4 Government

The government collects the pollution tax and uses it to finance its expenditure. Note that static nature of the model implies that government will not save and and its budget must be balanced ($G = \tau Z$). To avoid mixing fiscal policy and climate policy, we consider that government expenditure does not include any kind of redistribution neither in the form of public services nor in the form of transfer to the households. This assumption allows us to keep our focus on households' trade-off between consumption and environmental quality and to abstract from redistributional impacts of fiscal policy. Besides, it provides analytical tractability and convenience. Therefore, in line with Harberger (1962), Chiroleu-Assouline and Fodha (2006), Fullerton and Heutel (2007) and others, we consider that the government uses the collected tax revenues to buy the goods from the market which has no effect on the households' utility.

1.5 Households

Household i's utility $V(c_i, E)$ depends on its level of consumption (c_i) and the level of environmental quality (E).[16] We impose the following assumptions for the utility function:

Assumption 3. *The utility function $V(c_i, E)$ is additively separable in c_i and E ($V_{cE}(.)=0$), increasing and concave in c ($V_c(.) > 0$ and $V_{cc}(.) < 0$) and increasing and concave in E ($V_E(.) > 0$ and $V_{EE}(.) < 0$). We assume that:*

$$V(c_i, E) = v(c_i) + h(E) \tag{1.17}$$

These assumptions about the effects of consumption and environmental quality on utility are standard and widely used in the literature. However, the assumption on the additive separability is rather restrictive. In Section 1.8.1, we study the impact of relaxing this assumption but, for the rest of this section, we abstract from the cross relationship between consumption and environmental quality in the household's utility. This leads us to have a more clear analytic resolution.

[16]See Michel and Rotillon (1995) and Weitzman (2010) for a detailed discussion of this type of preferences.

Environmental quality is a decreasing function of pollution ($E(z)$ with $E'(z) < 0$). Thus we can rewrite the utility function as $V(c_i, E(z))$ $= U(c_i, z)$ where $U(.)$ is increasing and concave in c_i ($U_c(.) > 0$ and $U_{cc}(.) < 0$) and decreasing and concave in z ($U_z(.) < 0$ and $U_{zz}(.) < 0$). Thereafter we will use the utility function $U(.)$ in our analysis.

Due to the static nature of our framework, households that maximize their utility will consume all of their revenue which consists of the wage and the gross return of their capital. In Section 2.2.2, we showed that the wage and the interest rate are determined by the pollution tax in the partial competitive equilibrium. Therefore, in the general equilibrium, the consumption level of the household i will depend on the pollution tax and its wealth, that is

$$c_i(\tau, k_i) = w(\tau) + (1 + r(\tau))k_i \tag{1.18}$$

The following section characterizes the general equilibrium in this economy.

1.6 General Equilibrium

We first start by studying the goods market equilibrium, which implies that total consumption (public and private) must be equalized to total production:

$$Y(\tau) + X(\tau) = C(\tau) + G(\tau) = ((1 + r(\tau))\bar{K} + w(\tau)\bar{L}) + \tau Z(\tau) \tag{1.19}$$

The left hand side of equation (1.19) is the aggregate production in terms of numeraire price and the right hand side denotes total private and public consumption. Now we can investigate the effect of pollution tax on aggregate production, private and public consumption by looking at the derivative of equation (1.19) with respect to the pollution tax:[17]

$$Y'(\tau) + X'(\tau) = (r'(\tau)\bar{K} + w'(\tau)\bar{L}) + Z(\tau) + \tau Z'(\tau) = \tau Z'(\tau) < 0 \tag{1.20}$$

An increase in the pollution tax decreases the total private consumption due to the decrease in the factor revenues. This holds true even in the case where the wage increases in the pollution tax because the effect of the decrease in the interest rate on total private consumption dominates the gains from the increase in the wage.[18] Moreover, the aggregate production is also decreasing in the pollution tax. Hence there is no room for double dividend in this model. The impact on government revenue remains ambiguous since an increase in pollution tax leads to a decrease in the tax base.

Now we can characterize the general equilibrium in this economy:

Definition 2. *For a given pollution tax (τ), the unique general equilibrium for this economy is characterized by the vector of factor intensities in each technology $\{\alpha_z^X, \alpha_k^X, \alpha_l^X, \alpha_z^Y, \alpha_k^Y, \alpha_l^Y\}$, the vector of labor and capital prices $\{w, r\}$, the vector of the factors amounts employed in each technology $\{z_x, k_x, l_x, z_y, k_y, l_y\}$, the total production in each technology $\{X, Y\}$, the government spending $\{G\}$, the consumption level of each household $\{c_i\}_{i=0}^1$ and the total consumption $\{C = \int c_i\}$ such that:*

[17]See Appendix 1.9 for the proof.

[18]Note that in the case where the wage is increasing in the pollution tax, there may exist some households with a very low wealth such that their consumption increases in the pollution tax. Total consumption of the households, however, is always decreasing in pollution tax.

(i) The firms minimize their costs, thus the eight equations in (1.8 to 1.11) hold.

(ii) The markets clear, thus the resource constraints (1.12 and 1.13) hold.

(iii) The government budget is balanced ($G = \tau(z_x + z_y)$) hold.

(iv) Households consume all their revenue. (1.18) *holds for each i*

1.7 Preferred pollution tax of households

This section aims to investigate preferred pollution tax of households which is defined as the level of tax that maximizes household i's utility. Then we will examine how it is affected by capital endowment of households. In this paper, we consider progressivity and regressivity of the tax always in terms of welfare. Hence, the pollution tax progressive if it harms (favors) the poor less (more) than the rich. Then, households with a higher capital endowment will prefer a lower pollution tax if the tax is progressive (*vice versa* for regressivity):

$$\text{Pollution tax is progressive} \Longleftrightarrow \frac{\partial(\frac{\partial u(\tau,k_i)}{\partial \tau})}{\partial k_i} < 0 \Rightarrow \text{sign}(\frac{\partial \tau_i^{\star}(k_i)}{\partial k_i}) < 0$$

Therefore, all of our results about the impact of capital endowment on preferred pollution tax can be equivalently interpreted as progressivity/regressivity of the pollution tax in terms of welfare.

To find the preferred pollution tax of a household we consider the following maximization programme:

$$\max_{\{\tau \mid \tau \geq 0\}} \{U(c_i(\tau, k_i), z(\tau))\} \tag{1.21}$$

which leads to the following first order condition:

$$\frac{\partial U(c_i(\tau_i^\star, k_i), z(\tau_i^\star))}{\partial \tau_i^\star} = U_c(.)\frac{\partial c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star} + U_z(.)\frac{\partial z(\tau_i^\star)}{\partial \tau_i^\star} = 0 \tag{1.22}$$

Condition (1.22) clearly reflects the trade-off between higher consumption and better environmental quality. On the one hand, the pollution tax has an adverse effect on consumption due to its impact on factor prices which decreases the revenue of the household (the first term in the RHS of eq. (1.22)). This effect indeed has a negative impact on the household's utility. On the other hand, it decreases the level of pollution hence has a positive effect on the utility from the environmental well-being channel (the second term in the RHS of eq. (1.22)). Therefore one may expect that there is a preferred pollution tax for a household that balances these opposite effects.

In Proposition 2 we showed that when the firms are operating by using dirty and clean technologies, we may have a case such that the wage is increasing in the pollution tax ($w'(\tau) > 0$). In this case, the pollution tax may increase the total revenues of some households which have a low wealth because the increase in wage may dominate the loss from their gross capital return. Thus, the pollution tax will not impose a trade-off as in equation (1.22) for these households and their utility will obviously increase in tax. However, as shown in Proposition 4, there exists a threshold for pollution tax above which only the clean technology is used. Above this threshold, independent of their wealth, the trade-off in equation (1.22) will be valid for all households because when the firms are operating by using a single technology the wage decreases in pollution tax ($w'(\tau) < 0$) as shown in Proposition 1.

To proceed further, we assume the following:

Assumption 4. *Once $\tau_i^\star$ exists for household i, its marginal utility is decreasing with respect to the pollution tax (τ) at this tax level, that is*

$$\frac{\partial^2 U(c_i(\tau_i^\star, k_i), z(\tau_i^\star))}{\partial \tau_i^{\star 2}} < 0 \tag{1.23}$$

This assumption implies that the utility of household reaches a peak when the equation (1.22) holds. Note that while for discussing about preferred pollution tax we need the assumptions on the sign of the second derivative of utility function as well as on the existence of preferred pollution tax, we do not need any of these assumptions to analyze the progressivity/regressivity of the tax.

Equation (1.22) shows that household's preferred pollution tax depends on its wealth. To investigate the effect of an increase in the household's wealth on its preferred pollution tax, we take the derivative of equation (1.22) and solve it for $\partial \tau_i^\star / \partial k_i$ which yields the following result:[19]

$$\text{sign}\left(\frac{\partial \tau_i^\star(k_i)}{\partial k_i}\right) = \text{sign}\Big(\underbrace{U_{cc}(.)\frac{\partial c_i(\tau_i^\star, k_i)}{\partial k_i}\frac{\partial c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star}}_{>0\text{ ; Satiation effect}} + \underbrace{U_c(.)\frac{\partial^2 c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star \partial k_i}}_{<0\text{ ; Income burden effect}}\Big) \tag{1.24}$$

The first term in the RHS(1.24), which has a positive sign, can be called as the *satiation effect*. When a household is richer, its level of consumption is relatively higher and thus its marginal utility of consumption is lower. This results in a lower marginal rate of substitution between consumption and environmental quality. In other words,

[19] See See Appendix 1.9.

richer households care less about the loss from their consumption due to the pollution tax. Therefore, through this channel richer households would prefer a higher pollution tax.

The second term in the RHS(1.24) , which has negative sign, can be called as the *income burden effect.* It reflects the fact that, in absolute terms, richer households lose more from their consumption due to an increase in pollution tax. This is because of the fact that richer households have greater amount of capital invested in the market and so their revenue is more affected by the decline in return to capital. Consequently, through this channel richer households will prefer a lower pollution tax. Therefore, whether the households with higher capital endowment would prefer a higher or a lower pollution tax will depend on which one of these two effects dominates.

In the case that $v(c)$ in household utility has logarithmic form, we can analytically show that the dominating effect depends only on the pollution tax elasticity of consumption.

Proposition 5. *If the household's utility satisfies the properties given in Assumption (3) and assumption (4), and moreover $v(c_i) = log(c_i)$, then the preferred pollution tax of a household is increasing in its wealth if and only if the pollution tax elasticity of consumption is increasing in wealth. Formally:*

$$\mathrm{sign}\left(\frac{\partial \tau_i^\star(k_i)}{\partial k_i}\right) = \mathrm{sign}\left(\frac{\partial \epsilon_{c_i,\tau}}{\partial k_i}\right) \tag{1.25}$$

Proof. See Appendix 1.9. □

Proposition 5 shows that, for the logarithmic form of utility, the richer households want a higher environmental protection if and only if their percentage loss in consumption due to the pollution tax is lower than the poorer households. Since our framework is static and households consume all and only the revenues from their factor supplies, the pollution tax elasticity of consumption is decreasing in wealth if and only if the ratio of gross capital return to wage $(\frac{R}{w})$ decreases with respect to the pollution tax. In this case, the richer households will experience a higher percentage loss from their consumption due to an increase in the tax compared to the poorer households. This fact, combined with the assertion in Proposition 5 leads to the following result:

Proposition 6. *If the household's utility satisfies the properties given in Assumption (3) and assumption (4), and moreover $v(c_i) = log(c_i)$, the preferred pollution tax is increasing in the household's wealth if and only if the pollution tax elasticity of gross interest rate is greater (less negative) than the one of the wage. Formally:*

$$\text{sign}(\frac{\partial \tau_i^\star(k_i)}{\partial k_i}) = \text{sign}(\epsilon_{R,\tau} - \epsilon_{w,\tau}) \tag{1.26}$$

Proof. See Appendix 1.9. □

From Section 2.2.2 we know that $(\frac{R}{w})$ is increasing with respect to the tax in the case where firms operate by using a single technology and it is deceasing in the two-technology case. Combining these results with Proposition 6 leads us to the central claims of this subsection.

Proposition 7. *When firms operate using a single production technology, the preferred pollution tax of an household is increasing in its wealth and the tax is regressive, $\frac{\partial \tau_i^\star(k_i)}{\partial k_i} > 0$.*

Proof. Direct conclusion of Proposition 1 and Proposition 6. □

Proposition 8. *When firms operate using dirty and clean production technologies which satisfy the properties in Assumption 2, the preferred pollution tax of an household is decreasing in its wealth and the tax is progressive,* $\frac{\partial \tau_i^\star(k_i)}{\partial k_i} < 0$.

Proof. Direct conclusion of Proposition 2 and Proposition 6. □

Proposition 8 shows that when the pollution tax leads to a reallocation of factors in cleaner technologies, which are more labor intensive, the rich prefers a lower pollution tax compared to the low-income households. Therefore pollution tax is progressive in this case. The richer people in the society who own a larger share of capital lose a higher proportion of their income compared to the low income households. Consequently, the loss in their well-being due to the fall of income outweighs the benefits of a better environment, and their support for a pollution tax declines.

In the following section, we will discuss the outcome when some of the model assumptions are relaxed.

1.8 Discussion

1.8.1 The case of non-separable utility function

The assumptions on the utility function have crucial effects on the results presented in the previous section. An important one is the additive separability of utility of consumption and disutility of pollution, meaning $U_{cz} = 0$ in our framework. Michel and Rotillon (1995) studied the cases in which the utility function is non-separable, naming the case of $U_{cz} < 0$ as the "distaste effect" and the case of $U_{cz} > 0$ as the "compensation effect". They study the impact of these assumptions on the outcome within an endogenous growth framework. In this section, we will discuss how our results could differ when we consider a non-separable utility function.

Additive separability of the utility function with respect to consumption and environmental quality have two implications: (i) the marginal utility of consumption does not depend on pollution and (ii) the marginal utility of environmental quality is independent from the level of consumption. When this assumption is relaxed, the households' preferred pollution taxes will vary as the marginal utility of consumption depends on the environmental quality.

To evaluate the effect of $U_{cz}(.)$ on the household's preferred pollution tax and, hence, on progressiveness of the pollution tax, we rewrite equation (1.24) for the case in which $U_{cz}(.) \neq 0$:

$$\text{sign}(\frac{\partial \tau_i^\star(k_i)}{\partial k_i}) = \text{sign}(\underbrace{U_{cc}(.)\frac{\partial c_i(\tau_i^\star, k_i)}{\partial k_i}\frac{\partial c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star}}_{>0\text{ ; Satiation effect}} + \underbrace{U_c(.)\frac{\partial^2 c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star \partial k_i}}_{<0\text{ ; Income burden effect}} + U_{cz}(.)\underbrace{\frac{\partial c_i(\tau_i^\star, k_i)}{\partial k_i}}_{>0}\underbrace{Z'(\tau)}_{<0}) \quad (1.27)$$

We can see that another term is added in (1.24), which played crucial role in propositions 5 to 8. Equation 1.27 shows that the value of the new term will be added in either satiation effect or income burden effect depending on its sign.

When we consider the distaste effect ($U_{cz}(.) < 0$), which means that the marginal utility of consumption decreases in the level of pollution, the sign of last term will be positive and the cross effect of consumption and pollution is going to be added to the satiation effect. In this case, higher pollution tax improves the utility of households not only by enhancing environmental quality, but also by improving the marginal utility of consumption. As the rich consume more, the latter effect is more pronounced for them. From this channel, the rich wants a higher pollution tax. Considering all the effects that we discussed previously, taking into account the distaste effect makes the tax less progressive. In extreme cases where the distaste effect is very strong, it can even make the tax regressive compared to the separable utility case.

In the contrary case in which there is a compensation effect ($U_{cz}(.) > 0$), a higher consumption decreases the disutility of pollution. This makes the sign of the last term to be negative and it contributes in the income burden effect. This in turn makes the pollution tax more progressive compared to the separable utility case.

1.9 Conclusion

We showed that the households with uneven wealth endowments prefer different levels of pollution tax. This is due to the fact that wealth inequality implies two distinctions between the rich and the poor households: (i) their consumption levels are not the same and (ii) the amounts of capital that they invest in the market are different. In fact, these differences correspond to the channels that we identified as the determinant of the household's preferred pollution taxes which we called as the satiation effect and the cost of pollution tax effect. The satiation effect means that the marginal utility of consumption is lower for the richer households, henceforth, they are more willing to sacrifice from their consumption for a better environmental quality. The cost of pollution tax effect refers to the fact that the revenue of the rich is more reduced by the pollution tax due to their higher capital investment in the market. Furthermore, we showed that the effect that dominates depends on how the revenues of the households are affected by the increase in the pollution tax.

By using a general equilibrium framework, we showed that the impact of the pollution tax on the household revenue (which comes from the wage and the interest rate) depends on the characteristics of the production technologies employed by the firms. We identified the cases in which the wage and the interest rate move in the same or different direction as a response to an increase in the pollution tax. When the firms operate by using only one production technology, the pollution tax elasticity of wage and interest rate are identical which makes the rich to lose less than the poor from their consumption in percentage terms. Thus, in this case, the rich prefer a higher pollution tax and the tax is regressive. This result changes when the firms operate by using two technologies: (*i*) dirty and more capital intensive and (*ii*) cleaner and more labor intensive. In this case, an increase in the pollution tax leads to a reallocation of factors from the dirty technology to the clean one. This reallocation leads to a relatively higher decrease in the returns of capital. Consequently, in this case, the rich loses more than the poor from their consumption in percentage terms and thus they prefer a lower pollution tax and the tax is progressive.

Our set-up is new in the literature and it can suggest several new extensions. For example: (i) transforming the model into the dynamic framework allows to investigate intertemporal effects of environmental policies on capital accumulation and growth. (ii) Introducing consumer non-homothetic preferences towards dirty and clean products allows to capture both the sources and the uses sides of income. That framework can imply a hump-shaped relationship between income and support for pollution tax. (iii) Considering skill-heterogeneity where skills are perfect substitute can be very simple extension of this model. In that case we can expect again a hump-shaped elationship between income and support for pollution tax. (iv) A simple model of two countries with different wealth distributions, factor endowments and production technologies would allow to analyze concepts such as pollution heavens as well as to identify patterns of factors in response to environmental policies. (v) Finally, this study provides a potential benchmark for further analysis in political economics research concerning environmental policies and income inequality defined as top income shares.

Appendix A

A1: Proof of Proposition 1

We use the first order conditions given in (1.3 to 1.5). First we use (1.3) to obtain:

$$z(\tau) = F_1^{-1}(\tau; G(\bar{K}, \bar{L})) \tag{A.1}$$

Note that since $G(\bar{K}, \bar{L})$ is given and constant, it affects $z(\tau)$ as a parameter. By using the properties of the production function given in Assumption 1, we know that $F_{11}^{-1}(.,.) < 0$ hence

$$z'(\tau) < 0 \tag{A.2}$$

Now that we have $z(\tau)$, we replace it in equations (1.4 and 1.5) to get the following:

$$F_2(z(\tau), G(\bar{K}, \bar{L}))G_1(\bar{K}, \bar{L}) = r \tag{A.3}$$

$$F_2(z(\tau), G(\bar{K}, \bar{L}))G_2(\bar{K}, \bar{L}) = w \tag{A.4}$$

We can now compute the wage and interest rate as a function of pollution tax and how they change according to that.

$$r'(\tau) = z'(\tau)F_{21}(z(\tau), G(\bar{K}, \bar{L}))G_1(\bar{K}, \bar{L}) < 0 \tag{A.5}$$

$$w'(\tau) = z'(\tau)F_{21}(z(\tau), G(\bar{K}, \bar{L}))G_2(\bar{K}, \bar{L}) < 0 \tag{A.6}$$

since $z'(.) < 0$, $F_{21}(.) > 0$, $G_1(.) > 0$ and $G_2(.) > 0$ which completes the first part of the proof.

The elasticities of wage and interest rate respect to the pollution tax are:

$$\begin{aligned} \epsilon_{r,\tau} = \frac{r'(\tau)}{r(\tau)/\tau} &= \frac{z'(\tau)F_{21}(z(\tau), G(\bar{K}, \bar{L}))G_1(\bar{K}, \bar{L})\tau}{F_2(z(\tau), G(\bar{K}, \bar{L}))G_1(\bar{K}, \bar{L})} \\ &= z'(\tau)\frac{F_{21}(z(\tau), G(\bar{K}, \bar{L}))\tau}{F_2(z(\tau), G(\bar{K}, \bar{L}))} < 0 \end{aligned} \tag{A.7}$$

$$\begin{aligned} \epsilon_{w,\tau} = \frac{w'(\tau)}{w(\tau)/\tau} &= \frac{z'(\tau)F_{21}(z(\tau), G(\bar{K}, \bar{L}))G_2(\bar{K}, \bar{L})\tau}{F_2(z(\tau), G(\bar{K}, \bar{L}))G_2(\bar{K}, \bar{L})} \\ &= z'(\tau)\frac{F_{21}(z(\tau), G(\bar{K}, \bar{L}))\tau}{F_2(z(\tau), G(\bar{K}, \bar{L}))} = \epsilon_{r,\tau} < 0 \end{aligned} \tag{A.8}$$

$$\epsilon_{R,\tau} = \frac{R'(\tau)}{R(\tau)/\tau} = \frac{r(\tau)}{R(\tau)}\frac{r'(\tau)}{r(\tau)/\tau} = \frac{r(\tau)}{1 + r(\tau)}\epsilon_{r,\tau} \tag{A.9}$$

which completes the second part of the proof.

Note that this property implies the following relationships:

$$\frac{w(\tau)}{r(\tau)} = \frac{w'(\tau)}{r'(\tau)} = \frac{w''(\tau)}{r''(\tau)} \tag{A.10}$$

Equation (A.10) can be obtained as follows:

$$\frac{r'(\tau)}{r(\tau)} = \frac{w'(\tau)}{w(\tau)} \tag{A.11}$$

$$\Rightarrow Log(r'(\tau)) - Log(r(\tau)) = Log(w'(\tau)) - Log(w(\tau)) \tag{A.12}$$

$$\Rightarrow \frac{r''(\tau)}{r'(\tau)} - \frac{r'(\tau)}{r(\tau)} = \frac{w''(\tau)}{w'(\tau)} - \frac{w'(\tau)}{w(\tau)} \tag{A.13}$$

$$\Rightarrow \frac{w''(\tau)}{r''(\tau)} = \frac{w'(\tau)}{r'(\tau)} = \frac{w(\tau)}{r(\tau)} \tag{A.14}$$

A2: Proof of Proposition 2

We use the first order conditions (1.9 to 1.11) of the cost minimization problem in (1.7) to obtain the derived unit=production demands for factors in both of the two technologies. For the dirty technology we have $\left\{\alpha_z^X(\tau), \alpha_k^X(\tau), \alpha_l^X(\tau)\right\}$ and for the clean technology we have $\left\{\alpha_z^Y(\tau), \alpha_k^Y(\tau), \alpha_l^Y(\tau)\right\}$. From now on we will drop functional arguments (τ) for notational simplicity.

Let $\eta_x = \alpha_k^X/\alpha_l^X$, $\eta_y = \alpha_k^Y/\alpha_l^Y$, $\zeta_x = \alpha_z^X/\alpha_l^X$ and $\zeta_y = \alpha_z^Y/\alpha_l^Y$. By Definition 1 ($\alpha_z^X > \alpha_z^Y$, $\alpha_k^X > \alpha_k^Y$ and $\alpha_l^X < \alpha_l^Y$) we have $\eta_x > \eta_y$ and $\zeta_x > \zeta_y$. Perfect competition implies:

$$\tau\alpha_z^X + (1 + r(\tau))\alpha_k^X + w(\tau)\alpha_l^X = \bar{p} \tag{A.15}$$

$$\tau\alpha_z^Y + (1 + r(\tau))\alpha_k^Y + w(\tau)\alpha_l^Y = \bar{p} \tag{A.16}$$

where $\bar{p}$ is the price of the generic good and we take is as numeraire hence $\bar{p} = 1$. Now we will compute how the unit cost changes with the pollution tax. For that we take the derivative of equations (A.15 and A.16) respect to τ. Note that all the derived demands depend on the pollution tax, however, they are obtained from the cost minimization problem which means that when we apply the envelope theorem we will have $\tau a_z'(\tau) + r(\tau)a_k'(\tau) + w(\tau)a_l'(\tau) = 0$ for $i \in \{x, y\}$. Applying this to the derivative of equations (A.15 and A.16):

$$\alpha_z^X + r'(\tau)\alpha_k^X + w'(\tau)\alpha_l^X = 0 \tag{A.17}$$

$$\alpha_z^Y + r'(\tau)\alpha_k^Y + w'(\tau)\alpha_l^Y = 0 \tag{A.18}$$

We divide (A.17) by α_l^X and (A.18) by α_l^Y to obtain:

$$\zeta_x + r'(\tau)\eta_x + w'(\tau) = 0 \tag{A.19}$$

$$\zeta_y + r'(\tau)\eta_y + w'(\tau) = 0 \tag{A.20}$$

Subtracting (A.20) from (A.19) gives:

$$r'(\tau) = -\frac{\zeta_x - \zeta_y}{\eta_x - \eta_y} < 0 \text{ by Definition 1} \tag{A.21}$$

Furthermore, we multiply (A.20) by η_x/η_y and subtract the resulting equation from (A.19) to obtain:

$$w'(\tau) = \frac{\zeta_x\eta_y - \zeta_y\eta_x}{\eta_x - \eta_y} \tag{A.22}$$

The sign of $w'(\tau)$ depends on the relative factor intensities between the two technologies. We have:

$$w'(\tau) > 0 \text{ if } \frac{\zeta_x}{\eta_x} > \frac{\zeta_y}{\eta_y} \Leftrightarrow \frac{\alpha_z^X}{\alpha_k^X} > \frac{\alpha_z^Y}{\alpha_k^Y} \tag{A.23}$$

$$w'(\tau) = 0 \text{ if } \frac{\zeta_x}{\eta_x} = \frac{\zeta_y}{\eta_y} \Leftrightarrow \frac{\alpha_z^X}{\alpha_k^X} = \frac{\alpha_z^Y}{\alpha_k^Y} \tag{A.24}$$

$$w'(\tau) < 0 \text{ if } \frac{\zeta_x}{\eta_x} < \frac{\zeta_y}{\eta_y} \Leftrightarrow \frac{\alpha_z^X}{\alpha_k^X} < \frac{\alpha_z^Y}{\alpha_k^Y} \tag{A.25}$$

which completes the first part of the proof. For the elasticities, we can rewrite equations (A.15) and (A.16) as follows:

$$\zeta_x \tau + \eta_x(1 + r(\tau)) + w(\tau) = \frac{\bar{p}}{\alpha_l^X} \tag{A.26}$$

$$\zeta_y \tau + \eta_y(1 + r(\tau)) + w(\tau) = \frac{\bar{p}}{\alpha_l^Y} \tag{A.27}$$

Multiplying equation (A.26) by ζ_y and equation (A.27) by ζ_x and subtracting the latter from the former, we get:

$$\begin{aligned}(1 + r(\tau))(\zeta_y \eta_x - \zeta_x \eta_y) + w(\tau)(\zeta_y - \zeta_x) &= \bar{p}(\frac{\zeta_y}{\alpha_l^X} - \frac{\zeta_x}{\alpha_l^Y}) \\ &= \frac{\bar{p}}{\alpha_l^X \alpha_l^Y}(\alpha_z^Y - \alpha_z^X) < 0\end{aligned} \tag{A.28}$$

Dividing LHS of inequality (A.28) by $(\eta_x - \eta_y)$ and using equations (A.21) and (A.22), we can show:

$$-w'(\tau)(1 + r(\tau)) + w(\tau)r'(\tau) < 0 \tag{A.29}$$

Therefore:

$$\frac{r'(\tau)}{1+r(\tau)} < \frac{w'(\tau)}{w(\tau)} \Leftrightarrow \epsilon_{R,\tau} < \epsilon_{w,\tau} \tag{A.30}$$

Moreover, since $r' < 0$,we can conclude that: $\epsilon_{r,\tau} < \epsilon_{R,\tau} < 0$.
Finally, equation (A.23) define the conditions for the sign of $\epsilon_{w,\tau}$ and it completes the second part of the proof.

A3: Proof of Proposition 3

From equations (1.10) and (1.11), we have:

$$r = F_2^a(\alpha_z^X, G^a(\alpha_k^X, \alpha_l^X))G_1^a(\alpha_k^X, \alpha_l^X) \tag{A.31}$$

$$w = F_2^a(\alpha_z^X, G^a(\alpha_k^X, \alpha_l^X))G_2^a(\alpha_k^X, \alpha_l^X) \quad \text{for } a \in \{x, y\} \tag{A.32}$$

Dividing equation (A.31) by (A.32) we get:

$$\frac{r}{w} = \frac{G_1^a(\alpha_k^X, \alpha_l^X)}{G_2^a(\alpha_k^X, \alpha_l^X)} \tag{A.33}$$

Proposition 3 implies that $\frac{d(r/w)}{d\tau} < 0$ and so:

$$\frac{d(\frac{G_1^a(\alpha_k^X, \alpha_l^X)}{G_2^a(\alpha_k^X, \alpha_l^X)})}{d\tau} < 0 \Leftrightarrow \frac{d(\frac{a_k}{a_l})}{d\tau} > 0 \quad \text{for } a \in \{x, y\} \tag{A.34}$$

A4: Proof of Proposition 4

Resource Constraints for capital and labor imply that:

$$X\alpha_k^X + Y\alpha_k^Y = \bar{K} \tag{A.35}$$

$$X\alpha_l^X + Y\alpha_l^Y = \bar{L} \tag{A.36}$$

Solving equations (A.35) and (A.36) for X and Y will result in the followings:

$$X = \frac{\alpha_l^Y \bar{K} - \alpha_k^Y \bar{L}}{\alpha_k^X \alpha_l^Y - \alpha_l^X \alpha_k^Y} \tag{A.37}$$

$$Y = \frac{\alpha_l^X \bar{K} - \alpha_k^X \bar{L}}{\alpha_l^X \alpha_k^Y - \alpha_k^X \alpha_l^Y} \tag{A.38}$$

Therefore:

$$X = 0 \Leftrightarrow \frac{\alpha_k^Y(\tau_{clean})}{\alpha_l^Y(\tau_{clean})} = \frac{\bar{K}}{\bar{L}} \tag{A.39}$$

$$Y = 0 \Leftrightarrow \frac{\alpha_k^X(\tau_{dirty})}{\alpha_l^X(\tau_{dirty})} = \frac{\bar{K}}{\bar{L}} \tag{A.40}$$

The denominator in RHS of equation (A.39) is positive. Since $\frac{d(\frac{a_k}{a_l})}{d\tau} > 0 \quad for$ for $a \in \{x, y\}$, if pollution tax is higher than τ_{clean}, then the production in dirty technology will be negative which is not possible. Therefore, for pollution tax higher than τ_{clean}, economy will use only the clean technology. With the same method, it is easy to show that for pollution tax lower than τ_{dirty}, the economy will operate only by the dirty technology.

A5: Proof of Corollary 1

From equations (A.39) and (A.40), we know that:

$$\frac{d(\frac{\alpha_k^Y(\tau_{clean})}{\alpha_l^Y(\tau_{clean})})}{d(\frac{\bar{K}}{\bar{L}})} = 1 > 0 \tag{A.41}$$

$$\frac{d(\frac{\alpha_k^X(\tau_{dirty})}{\alpha_l^X(\tau_{dirty})})}{d(\frac{\bar{K}}{\bar{L}})} = 1 > 0 \tag{A.42}$$

And from Proposition 4 we know that $\frac{d(a_k(\tau)/a_l(\tau))}{d\tau} > 0$ for $a \in \{x, y\}$. Therefore:

$$\frac{d(\tau_{clean})}{d(\frac{\bar{K}}{\bar{L}})} > 0 \tag{A.43}$$

$$\frac{d(\tau_{dirty})}{d(\frac{\bar{K}}{\bar{L}})} > 0 \tag{A.44}$$

Appendix B

Multiplying equation (A.17) by total production of the dirty technology, (X), and Multiplying equation (A.18) by total production of the clean technology, (Y), results in the followings:

$$Z_x + r'(\tau)k_x + w'(\tau)l_x = 0 \tag{B.1}$$

$$Z_y + r'(\tau)k_y + w'(\tau)l_y = 0 \tag{B.2}$$

By adding the two last equations, we have:

$$Z = -(r'(\tau)\bar{K} + w'(\tau)\bar{L} = -C'(\tau) \tag{B.3}$$

Using equation (B.3) in the RHS of the first equality in equation (1.20), will leads to the second equality of that equation. Moreover, since $Z > 0$, total private consumption is decreasing in pollution tax.

Appendix C

Appendix C1: Proof for equation (1.24)

We start from the first order condition resulted from household's maximization programme given in equation (1.21):

$$\frac{\partial U_i(c_i(\tau_i^\star, k_i), z(\tau_i^\star))}{\partial \tau_i^\star} = U_c(.)\frac{\partial c_i(\tau_i^\star, k_i)}{\partial \tau_i^\star} + U_z(.)\frac{\partial z(\tau_i^\star)}{\partial \tau_i^\star} = 0 \tag{C.1}$$

To find $\frac{\partial \tau_i^\star(k_i)}{\partial k_i}$ we take the derivative of (C.1) with respect to k_i at $\tau_i^\star(k_i)$:

$$\begin{aligned}
&U_{cc}(.)\frac{\partial c}{\partial k_i}c_1(\tau, k_i) + U_{cz}(.)z'(\tau)\frac{\partial \tau^\star}{\partial k_i}c_1(\tau, k_i) + U_{cc}(.)(c_1(\tau, k_i))^2\frac{\partial \tau^\star}{\partial k_i} \\
&+ U_c(.)c_{11}(\tau, k_i)\frac{\partial \tau^\star}{\partial k_i} + U_c(.)c_{12}(\tau, k_i) + U_{cz}(.)c_2(\tau, k_i)z'(\tau) \\
&+ U_{cz}(.)c_1(\tau, k_i)\frac{\partial \tau^\star}{\partial k_i}z'(\tau) + U_{zz}(.)(z'(\tau))^2\frac{\partial \tau^\star}{\partial k_i} + U_z(.)z''(\tau)\frac{\partial \tau^\star}{\partial k_i} = 0
\end{aligned}$$

Setting $U_{cz}(.) = 0$ (by Assumption 3) and collecting $\frac{\partial \tau^\star}{\partial k_i}$ we obtain:

$$\frac{\partial \tau^\star(k_i)}{\partial k_i} = -\frac{S_1}{S_2} \tag{C.2}$$

$$\text{where } S_1 = U_{cc}(.)c_2(\tau, k_i)c_1(\tau, k_i) + U_c(.)c_{12}(\tau, k_i) \tag{C.3}$$

$$\begin{aligned} S_2 =& U_{cc}(.)(c_1(\tau, k_i))^2 + U_c(.)c_{11}(\tau, k_i) + U_z(.)z''(\tau) \\ &+ U_{zz}(.)(z'(\tau))^2 \end{aligned} \tag{C.4}$$

Equation (C.4), S_2, corresponds to the second order condition and it is negative ($S_2 < 0$) by Assumption 4 . Therefore S_1 determines the sign of $\frac{\partial \tau^\star}{\partial k_i}$.

Appendix C2: Proof for Proposition 5

If $v(c_i) = log(c_i)$, then, $U_c(.) = \frac{1}{c_i}$ and $U_{cc}(.) = \frac{-1}{c_i^2}$. By replacing these two equations in equation (C.3), we will have:

$$s_1 = -\frac{1}{c_i^2}\frac{\partial c_i}{\partial k_i}\frac{\partial c_i}{\partial \tau} + \frac{1}{c_i}\frac{\partial^2 c_i}{\partial k_i \partial \tau} \tag{C.5}$$

And equivalently:

$$s_1 = \frac{\partial(\frac{1}{c_i}\frac{\partial c_i}{\partial \tau})}{\partial k_i} = \frac{1}{\tau}\frac{\partial \epsilon_{c_i,\tau}}{\partial k_i} \tag{C.6}$$

Appendix C3: Proof for Proposition 6

$$\epsilon_{c_i,\tau} = \frac{\partial c_i}{\partial \tau}\frac{\tau}{c_i} = \frac{r'(\tau)k_i + w'(\tau)}{(1+r(\tau))k_i + w(\tau)}\tau \tag{C.7}$$

Therefore:

$$\begin{aligned} \frac{\partial \epsilon_{c_i,\tau}}{\partial k_i} &= \frac{r'(\tau)c_i - (1+r(\tau))c_i'}{c_i^2}\tau = \frac{\tau}{c_i}(r'(\tau)w(\tau) - (1+r(\tau))w'(\tau)) \\ &= \frac{(1+r(\tau))w(\tau)}{c_i^2}(\epsilon_{R,\tau} - \epsilon_{w,\tau}) \end{aligned} \tag{C.8}$$

Using equation C.8 and equation C.6, we can get:

$$s1 = \frac{(1+r(\tau))w(\tau)}{\tau c_i^2}(\epsilon_{R,\tau} - \epsilon_{w,\tau}) \tag{C.9}$$

Which establishes the prove for the proposition 7.

Appendix D: The case of n technologies

We claim that in our framework, where the economy is open and operating in n-sectors (thus, prices in all the sectors are fixed), or equivalently, where the economy is closed but producing and consuming only one generic good with n-technologies, the economy will operate using maximum two sectors/technologies.

We have endowment constraints:

$$\sum_{i=1}^{n} k^i = \bar{K} \tag{D.1}$$

$$\sum_{i=1}^{n} l^i = \bar{L} \tag{D.2}$$

For each sector i, we have: $Q_i = F^i(z^i, G^i(k^i, l^i))$ which has a market price p_Q^i that is exogenously given. The prices of capital and labor (r and w) are endogenously determined, however, the price of z (τ) is exogenously given (by the government). The firms solve the following problem:

$$\max_{\{z_i,k_i,l_i\}} \left\{ \sum_{i=1}^{n} (p_Q^i F^i(z^i, G^i(k^i, l^i)) - rk^i - wl^i - \tau z^i) \right\}$$
$$\text{subject to (D.1), (D.2) and } z^i \geq 0 \ \forall i$$

First order conditions for an interior solution are:

$$p_Q^i F_1^i(z^i, G^i(k^i, l^i)) = \tau \tag{D.3}$$

$$p_Q^i F_2^i(z^i, G^i(k^i, l^i)) G_1^i(k^i, l^i) = r \tag{D.4}$$

$$p_Q^i F_2^i(z^i, G^i(k^i, l^i)) G_2^i(k^i, l^i) = w \tag{D.5}$$

Therefore, we have:

$\{D.1, D.2, D.3, D.4, D.5\} \Rightarrow 3n+2$ equations and $\{\{k^i, l^i, z^i\}, r, w\} \Rightarrow 3n+2$ variables.

Now we will show that if the functions $F(.)$ and $G(.)$ are homogeneous of degree 1 then these equations are not independent when $n > 2$. Therefore the solution for $n > 2$ does not exist. In other words, it is not possible that the economy operates with more than two technologies. To show that, we define:

$$\eta^i = \frac{k^i}{l^i} \tag{D.6}$$

$$\zeta^i = \frac{z^i}{l^i} \tag{D.7}$$

Using the property of homogenous of degree 1 for $F(.)$ and $G(.)$, we can rewrite equations (D.3) to (D.5) as follows:

$$p_Q^i F_1^i(\frac{\zeta^i}{G^i(\eta^i, 1)}, 1) = \tau \tag{D.8}$$

$$p_Q^i F_2^i(\frac{\zeta^i}{G^i(\eta^i, 1)}, 1) G_1^i(\eta^i, 1) = r \tag{D.9}$$

$$p_Q^i F_2^i(\frac{\zeta^i}{G^i(\eta^i, 1)}, 1) G_2^i(\eta^i, 1) = w \tag{D.10}$$

For n sectors, we have $\{\{\eta^i, \zeta^i, k^i, l^i, z^i\}, r, w\} \Rightarrow 5n+2$ variables and $(D.1, D.2, D.6, D.7, D.8, D.9, D.10) \Rightarrow 5n+2$ equations. At this point, the number of equations equals the number of variables and, thus, the system of equations seems to have a solution. However, a subset of this equation system, equations $(D.8, D.9, D.10)$ contain $3n$ equations with $2n+2$ variables. Therefore, if $n > 2$ then the number of equations is greater than the number of variables. This fact concludes that the system of equations are not independent. Hence there is no solution for

$n > 2$ when all of the n-technologies are being operated by the economy. In other words, the economy will use maximum two technologies for a given τ.

In fact, we can generalize the results above. Consider an economy with n-technologies (sectors) where all of the technologies are homogenous of degree 1 and they use m factors as inputs. In the case where the prices of s factors are given, meaning that $m-s$ factors' prices are determined endogenously (and their total amount must be constrained by endowment or ceiling constraints), we can conclude that maximum $m-s$ technologies will be operated by the economy.

Appendix E: An alternative setting: pollution as a byproduct

In this alternative setting the firms are involved in two processes. In the first process, they hire capital and labor (k^P, l^P) to produce the final good. Pollution (z) is byproduct of this process. Since we assume that the pollution is taxed (τ), the firms will get involved in the abatement activities in which they use capital and labor (k^A, l^A) to produce equipment that is used to reduce pollution. Therefore, in this alternative setting, pollution is a function of final good production $(H(k^P, l^P))$ and abatement process $(B(k^A, l^A))$:

$$
\begin{aligned}
&z = \Phi(H(k^P, l^P), B(k_k^A, l^A)) \\
&\quad \text{Where:} \quad \Phi_1(.) > 0, \Phi_2(.) < 0, \Phi_{11}(.) > 0, \Phi_{22}(.) > 0
\end{aligned}
$$

where j^P and j^A are demands of factor j for production of final good and for pollution abatement respectively. Since factor prices and pollution tax are given to the firms, their cost-minimization problem for producing one unit of final good is as follows:

$$\min_{\{a_z,a_k,a_l\}} \Big\{(a_k^P + a_k^A)r + (a_L^P + a_L^A)w + \Phi(H(a_k^P, a_L^P), B(a_k^A, a_L^A))\tau)\Big\} \tag{E.1}$$

$$\text{subject to: } H(a_k^P, a_L^P) = 1 \tag{E.2}$$

Here, a_j^P and a_j^A are demand of factor j for unit production of final good and for corresponding pollution abatement respectively. Factor demands in our main setting a_z, a_k, a_l can be translated to this setting as follows:

$$a_z = \Phi(H(a_k^P, a_L^P), B(a_k^A, a_L^A)) \tag{E.3}$$

$$a_k = a_k^P + a_k^A \tag{E.4}$$

$$a_l = a_L^P + a_L^A \tag{E.5}$$

Constant returns to scale form assumption for $F(.)$ and $G(.)$ in our main setting can be translated to constant returns to scale property of $H(.)$, $B(.)$ and $\Phi(.)$ in this alternative setting. Firms' minimization problem leads to the following first order conditions:

$$\begin{aligned} r &= H_1(a_k^P, a_L^P)(1 - \Phi_1(H(a_k^P, a_L^P), B(a_k^A, a_L^A))\tau) \\ &= \tau\Phi_2(H(a_k^P, a_L^P), B(a_k^A, a_L^A))B_1(a_k^A, a_L^A) \end{aligned} \tag{E.6}$$

$$\begin{aligned} w &= H_2(a_k^P, a_L^P)(1 - \Phi_1(H(a_k^P, a_L^P), B(a_k^A, a_L^A))\tau) \\ &= \tau\Phi_2(H(a_k^P, a_L^P), B(a_k^A, a_L^A))B_2(a_k^A, a_L^A) \end{aligned} \tag{E.7}$$

Besides, resource constrains imply:

$$Y(a_k^P + a_k^A) = \bar{K} \tag{E.8}$$

$$Y(a_l^P + a_l^A) = \bar{L} \tag{E.9}$$

$$\text{Where:} Y = H(\frac{a_k^P \bar{K}}{a_k^P a_k^A}, \frac{a_l^P \bar{L}}{a_l^P a_l^A}) \tag{E.10}$$

Equations (E.6) to (E.10) provides seven equations and seven variables: $\left\{a_k^P, a_L^P, a_k^A, a_L^A, w, r, Y\right\}$. Therefore, factor demands and input prices can be found as a function of pollution tax (τ). For the sake of notation simplicity, in the following, we don't write (τ) knowing that all these variables are function of this variable.

As we explained in Section 2.1, the assumption of functional separability directly implies that, once there is only one technology used in the economy, wage and interest rate will have the identical pollution tax elasticity. Now, we can investigate the implication of this result in this alternative setting. Below, we will prove that, in this alternative setting, relative price of wage to interest rate remains unchanged, if and only if, production process and pollution abatement process have identical relative factor intensity.

Dividing equation (E.6) by equation (E.7) results in:

$$\frac{r}{w} = \frac{H_1(a_k^P, a_L^P)}{H_2(a_k^P, a_L^P)} = \frac{B_1(a_k^A, a_L^A)}{B_2(a_k^A, a_L^A)} \tag{E.11}$$

Thus:

$$\frac{d(\frac{r}{w})}{d\tau} = 0 \Rightarrow \begin{cases} \frac{d(\frac{H_1(a_k^P, a_l^P)}{H_2(a_k^P, a_l^P)})}{d\tau} = 0 \\ \frac{d(\frac{B_1(a_k^A, a_l^A)}{B_2(a_k^A, a_l^A)})}{d\tau} = 0 \end{cases} \Rightarrow \begin{cases} \frac{d(\frac{a_k^P}{a_l^P})}{d\tau} = 0 \\ \frac{d(\frac{a_k^A}{a_l^A})}{d\tau} = 0 \end{cases} \tag{E.12}$$

Since $H(.)$ is constant returns to scale and by definition $H(a_k^P, a_L^P) = 1$, the first equality in equation (E.12) implies that a_k^P and a_l^P are constant. Therefore:

$$a_k^{P\prime} = a_l^{P\prime} = 0 \tag{E.13}$$

Moreover, resource constraint and CRS property of production function implies the following:

$$\frac{a_k^P + a_k^A}{a_l^P + a_l^A} = \frac{\bar{K}}{\bar{L}} \tag{E.14}$$

Making derivative from equation (E.14) and applying equation (E.13) leads to the following:

$$a_k^{A\prime}(a_l^P + a_l^A) = a_l^{P\prime}(a_k^P + a_k^A) \underbrace{\Rightarrow}_{\text{by eq. (E.12)}} a_k^A a_l^P = a_l^A a_k^P \Rightarrow \frac{a_k^A}{a_l^A} = \frac{a_k^P}{a_l^P} \tag{E.15}$$

The intuition behind this observation is that if pollution tax increases, firms will hire more capital and labor for abatement process. In overall, hence, the input hired in production process will decrease while that hired in pollution abatement process will increase. Consequently, if, compared to the former process, the latter uses one factor relatively more intensively than the other one, the price of that factor will increase relatively. Hence, relative price of factors will remain constant only if both process employ the factors with the same relative intensity.

Finally, we can investigate what dirty and clean technology mean when our main setting is transformed to this alternative one: If two production technologies, $(H^d(.), H^c(.))$,are available, $H^d(.)$ is dirty if and only if the pollution it generates to produce one unit of final good is more than the pollution that $H^c(.)$ generates for producing the same amount of final good.

Chapter 2

Foreign aid, public investment and liberalization of capital market

Abstract

This paper studies the impact of liberalization of capital market on the performance of foreign aid (FA). I consider two cases where FA is transferred to the households and where it is used to finance public investment. Two sources of endogenous productivity growth is considered: (i) public investment (ii) Learning-by-doing generated by tradable sector. Saving is endogenous. I compare two recipient economies with closed and open capital market. I show that transferred-aid reduces productivity and growth through de-industrialization if the capital market is liberalized. In the case of closed capital market transferred-aid can improve the growth (through improving the accumulation of capital) if LBD effect and consumption intensity to N-sector are small. On the contrary, the effect of invested-aid on growth is positive only if the quality of aid is high and the LBD effect and the intensity of public investment to N-sector are low. In this case, the effect of invested-aid on productivity is higher in the case of closed capital market. Nevertheless, productive foreign aid crowds out capital accumulation if capital market is closed while it leads to capital inflow if capital market is open. I show that the impact of invested-aid on GDP is more important for financially liberalized economy if LBD effect is low and private consumption is not very intensive to the N-sector.

Keywords: foreign aid, Dutch disease, LBD effect, capital market liberalization, endogenous growth.

JEL-Classification: O14, O24, H54, F35

2.1 Introduction

The increase in foreign aid and the other forms of unilateral sovereign capital transfers motivated a large number of studies on the effectiveness of foreign aid during the last forty years. In the post-World War II era, capital transfers have increasingly taken the form of development assistance or foreign aid.[1] Several U.N. reports and declarations have called for a dramatic increase in Official Development Assistance (ODA) to achieve the Millennium Development Goals. Besides, EU has designed and implemented Structural Funds program to assist below-average per capita incomes and low growth rates member nations to catch up and transit into the union. Nevertheless, the correlation between foreign aid and economics growth has been questioned by many economists (See Hansen and Tarp (2000) for a review) and there has been a large number of discussions about the magnitude and the design of these assistance.

The case studies on the effectiveness of foreign aid have found different results for different countries. For example, Levy (2007) finds that Chad by investing on education, infrastructures and institutions has benefited (in terms of growth) from foreign aid. On the contrary, Feeny (2005) finds little evidence that aid and its various components have contributed to economic growth in Papua New Guinea. Michalopoulos and Sukhatme (1989) conclude that the cross-country evidence is ambiguous.

In a much cited paper, Burnside and Dollar (1997), using panel growth regressions and using an interaction term between aid and an

[1]See Brakman and Van Marrewijk (1998).

index of economic policy show that foreign aid is effective for growth when it is complemented by good economic policy-making by the recipient governments. This paper, however, has been criticized by several papers, including Dalgaard and Hansen (2001), Easterly et al. (2003), which show that the results of Burnside and Dollar (1997) are fragile and data dependent. Finally Boone (1996) which attracted particular attention, concludes that aid has no effect on growth. In a nutshell, as Chatterjee and Turnovsky (2005) puts it: “there seems to be no emerging consensus on whether foreign aid can promote growth in poor countries.”

The shortcoming results in empirical studies about aid-growth relationship is to a large extent due to the lack of rich and sophisticated theoretical frameworks that would identify the mechanisms through which aid affects the growth. Without identifying these lines of causality there is no wonder that the empirical results are not conclusive. The aim of this paper is to contribute to the enrichment of the theoretical literature in this topic and to suggest new factors and policies which must be taken into account in the aid-growth analysis.

According to the existing growth literature on aid effectiveness, the most important channels through which aid affects the growth are: (i) private capital accumulation, (ii) public investment, (iii) Dutch disease and de-industrialization effect and (iv) political and institutional incentives.[2] On the one hand, temporary foreign aid, if transferred to the households can boost the saving and *possibly* the accumulation of capital. The first generation of aid-growth literature focused on this

[2]The last channel is not the focus of this paper. See Adam and O’Connell (1999) and Svensson (2000) as some examples in this line of study.

line of causality with sometimes naive conclusions that one dollar aid will be translated to one dollar of private saving (Rosenstein-Rodan (1961)). In a more recent paper, Chatterjee and Turnovsky (2005) conclude that the impact of an aid program on the accumulation of private capital depend on (i) the elasticity of substitution in production, (ii) whether the aid is permanent or temporary, and (iii) whether the aid is tied to public investment or not. Tied foreign aid is defined as a foreign aid which is obliged by donors to be used to finance productivity-enhancing public investment (e.g. infrastructures).

Besides, foreign aid can improve the productivity and growth by financing the government's investment in infrastructures and the other forms of productivity-enhancing public investments. Between 65% and 75% of official development assistance have been fully or partially tied to public investment.[3] Some papers in aid-growth have focused in this line of causality (e.g. Dalgaard (2008), Kalaitzidakis and Kalyvitis (2008) and Chatterjee et al. (2003)). Chatterjee et al. (2003) point out a sharp contrast between the impacts of tied and untied foreign aids on growth and productivity; arguing that publicly-invested-aid always work better than transferred-aid since it will increase the productivity of the economy.

On the other hand, foreign aid can be destructive for growth through Dutch disease and Learning-by-doing (LBD) externality. Dutch disease and its associated LBD effect are the focal points in natural resource-growth literature and are identified as the most important economic explanations for the curse of natural resource (See Van der Ploeg (2011) for a review). Similarly, the literature working on aid-growth relation-

[3] World Bank (1994).

ship, have identified Dutch disease as one of the sources through which aid may not be effective to boost the growth. (see Rajan and Subramanian (2005), McKinley (2009), Rajan and Subramanian (2011), Prati and Tressel (2006) and Bevan and Adam (2004)).

Foreign aid, similar to natural resource revenue, provides the economy with some windfall revenue which lead to Dutch disease characterized by (i) real appreciation of currency (at least in short term) and (ii) de-industrialization: The reallocation of resources from the tradable sector (henceforth the T-sector) to the non-tradable sector (henceforth the N-sector).[4] Empirical and theoretical papers in natural resource curse have identified T-sector (exporting and specially manufacturing sector) as the source of LBD and endogenous technological progress (see Sachs and Warner (1995), Van Wijnbergen (1984)). Therefore, de-industrialization influences negatively the productivity of the economy through diminishing the technological progress. If there is no LBD externality, Dutch disease will not have any long term impact in long run. But, in the presence of LBD externality, Dutch disease can deteriorate the long-run growth.

Knowing these mechanisms, some crucial questions must be addressed: Does invested-aid has always positive effect on productivity and growth? If not, under which conditions invested-aid can boost growth? Does liberalization of capital market plays a role in aid-growth relation? Does invested-aid always perform better than transferred-aid? Is it possible that for some given aid, turning invested-aid to transferred-aid leads to an improvement in growth? This paper by es-

[4]See Rajan and Subramanian (2005) for some empirical evidences of Dutch disease impact of aid.

tablishing a two-sector and two-period model, answers to these questions and identify some factors which are crucial in addressing to these questions.

I account for two sources of endogenous productivity growth: (i) public investment and (ii) LBD effect generated by the T-sector. Moreover, the model allows for endogenous saving and capital accumulation. This enables us to investigate the interactions between these three channels. By comparing the two cases of perfectly open capital market and closed capital market, I contrast impacts of the two types of the aid (transferred-aid and invested aid) in economies with different level of capital openness. I show that the efficiency of each type of aid and the best allocation of aid between these two types depend on the openness of financial market.

To the best of my knowledge, there has been no paper considering these three channels at the same time. For example, Chatterjee et al. (2003), Chatterjee and Turnovsky (2005) and Agénor et al. (2008) do not take into the account LBD externality. Ignoring the external LBD effect made them to conclude that, as long as labor supply is inelastic, transferred-aid has no long run impact on growth. This result can not be supported by empirical studies which have shown the possibility of negative effect of foreign aid on growth.

However, Adam and Bevan (2006), considering both public investment effect and LBD effect of aid, finds that the impact of enhanced aid on growth is less straightforward than the simple models of aid suggest. This result seems more compatible with empirical results. Adam and Bevan (2006) focus on the possibility of sector-specific bias in productivity generated by public investment. Nevertheless, they take the private saving and, hence, private capital accumulation as exogenous. Therefore, they do not take into account the effects that foreign aid can have on capital accumulation through LBD extenality and public investment. Besides, assuming exogenous saving abstracts the role that financial liberalization can play otherwise.

Another important contribution of this paper is investigating the influence of financial liberalization on the macro impacts of foreign aid. The influence of the liberalization of financial market on aid-growth has not been studied by previous literature, even though, as this paper will suggest, it can play important role in aid-growth relationship through its influence on the accumulation of capital. The impact of liberalizing of capital market, when the economy is facing windfall income, has been studied by Ismail (2010). In that study, the channel through which the openness of financial market plays role is different capital intensity of T-sector and N-sector: if the T-sector is relatively more capital intensive, windfall income leads to out flow of capital. Therefore, Ismail (2010) concludes that closed capital market operates better when an economy receives windfall income.

Even though the source of windfall income in that paper is natural resource, the same mechanism can play role when the economy receives windfall income from foreign aid. Nevertheless, the static paper of Ismail (2010) does not consider the interaction of financial liberalization with possible supply effects of windfall income through public investment and Dutch disease. In this paper the mechanism is through the impact of financial liberalization on the accumulation of private capital when foreign aid alters the productivity of the economy through public investment and LBD externality. Hence, no wonder that, contrary to Ismail (2010), this paper suggests that liberalization of financial market can impact positively the effectiveness of aid. More precisely, this paper suggests that financial liberalization can have positive effect on growth if the aid is invested in public productive goods. For example *if* invested-aid succeeds to boost the productivity, the economy will be more attractive for foreign investors. Therefore, if capital market is open, invested-aid leads to more capital inflow. On the contrary, if the capital market is closed, invested-aid discourages private saving through inter-temporal substitution effect. Therefore, in the case of closed capital market, productive foreign aid deteriorates the accumulation of private capital. Consequently, invested-aid can be more effective if the capital market is open.

The rest of paper will be as follows: section 2.2 introduces the general features of the model and defines the equilibrium for two cases of open and closed capital markets. Section 2.3 considers the aid that is entirely transferred to the households (transferred-aid). The impact of transferred-aid on productivity, growth, capital accumulation and size of the T-sector is studied and compared for two similar economies with open and closed capital markets. It is shown that in both cases transferred-aid leads to a shrinkage in the T-sector and to the deterioration of productivity. These effect are higher if capital market is closed. Moreover, transferred-aid will decline domestic capital and GDP if capital market is open. Transferred-aid, however, encourages the accumulation of capital if the financial market is closed. It is shown that the impact of transferred-aid in the two economies, on GDP depends on the importance of LBD effect and intensity of private consumption with respect to N-sector.

In section 2.4, I contrast the previous results with the impacts of invested-aid. I show that invested-aid leads to de-industrialization. Nevertheless, the impact of invested-aid on productivity is likely to be positive if the quality of public investment is high, LBD effect is relatively small and public investment is not very intensive to N-sector final goods. For the case in which this impact is positive (defined as effective invested-aid), de-industrialization is more pronounced if the capital market is open. Therefore, invested-aid is less effective to enhance the productivity if capital market is open. On the other hand, if capital market is closed, the effective invested-aid crowds out the private capital accumulation while it leads to capital inflow if capital market is open. Therefore, it remains ambiguous if liberalization of financial market enforces the positive impact of effective invested-aid on GDP growth. I will show that opening the capital market has favorable impact if LBD effect is relatively small and intensity of private consumption with respect to N-sector is low. In section 2.5, I discuss the optimal (in terms of growth) allocation of aid between invested-aid and transferred-aid for two cases of open and closed capital market. Section 2.6 discusses some of the assumptions of the model. Finally, section 2.7 concludes.

2.2 The General Model

In this section, I introduce the general features of the model. I establish a two-period model with two sectors: T-sector and N-sector. I assume a small open economy. Basket of consumption consists of the final goods produced in these two sectors. In the first period, the government receives windfall foreign aid.[5] The government can allocate this windfall revenue between non-productive expenditure (transfer to households) and productive public investment (e.g. investment on infrastructures and $R\&D$). Firms in each sector operate in perfect competition market and produce by hiring private capital and inelastic labor provided by the households. The productivity/technology is subject to endogenous progress originated from public investment and Learning-by-doing generated by the T-sector. I consider and compare two economies with open and closed capital market.

2.2.1 Households

I assume a continuum of homogeneous households normalized to one. Households live for two periods. The utility of the representative household depends on the basket of consumption. For simplicity, I assume that the household's utility is logarithmic and time separable:

$$U(\bar{C}_1, \bar{C}_2) = Log(\bar{C}_1) + \beta Log(\bar{C}_2) \tag{2.1}$$

Where $\bar{C}_t$ is basket of private consumption at time t and β is discount rate. Note that the government expenditure (G) is not directly in the utility function of the households. In fact government expenditure can have two different forms: (i) public goods/services and (ii) public investment. By definition, while the former has direct impact on individual utility, the latter influences the productivity and not directly the household utility. Assuming no asymmetry of information and homogeneity among the households, agents are indifferent to enjoy public services/goods or to receive direct transfer which enables

[5] windfall income can be from natural resource revenue as well.

them to buy the same services from private market. Therefore, we can assume that the government privatizes all its non-productive services and compensate households with some direct transfers. By doing so, I eliminate utility-based public services from the model. Thus, in the rest of the model, public investment is the only form of government expenditure and it does not have a direct impact on households utility.

The household can save or dissave in the first period to maximize his inter-temporal utility. One unit of saving is transformed to one unit of private investment and, thus, one unit of private capital if the capital market is closed (for simplicity I assume no depreciation of capital). If the capital market is open, however, this equality will not hold any more. In this case, the gap between net private saving and net accumulation of domestic capital represents the net non-sovereign capital outflow. Therefore, in the case of open capital market, one must distinguish between the capital owned by domestic households ($\tilde{K}$) and the capital which is used inside the economy (K).

At time t, the representative household's revenue consists of the wage in the return to his inelastic labor supply (w_t), the the return to the private capital owned by him ($r_t\tilde{K}_t$) and the net transfer (TR_t) from the government (lump-sum tax if $TR < 0$). The gap between his revenue and his consumption expenditure is his net saving: $\tilde{K}_{t+1} - \tilde{K}_t$:

$$\bar{P}_{\bar{C},t}\bar{C}_t + \tilde{K}_{t+1} = (1 + r_t)\tilde{K}_t + w_t + TR_t \tag{2.2}$$

where $\bar{P}_{C,t}$ represents the price level of the private basket of consumption at time t. Total endowment of capital in the first period ($\tilde{K}_1$) is given. The representative household maximizes his inter-temporal utility subject to his budget constraint:[6]

$$\max_{\{\bar{C}_1,\bar{C}_2,\tilde{K}_2\}} \left\{U(\bar{C}_1,\bar{C}_2) = Log(\bar{C}_1) + \beta Log(\bar{C}_2)\right\}$$

$$\text{subject to } \begin{cases} \bar{P}_{\bar{C},1}\bar{C}_1 + \tilde{K}_2 = (1+r_1)\tilde{K}_1 + w_1 + TR_1 \\ \bar{P}_{\bar{C},2}\bar{C}_2 = (1+r_2)\tilde{K}_2 + w_2 + TR_2 \end{cases}$$

This maximization problem leads to the standard consumption smoothing rule represented in the following equation:

$$\bar{C}_2 = \beta(1+r_2)\frac{\bar{P}_1}{\bar{P}_2}\bar{C}_1 \tag{2.3}$$

If households have perfect access to the international financial market, then r_2 is equal to the exogenous international interest rate $r^\star$. On the contrary, if the capital market is closed, r_2 will be determined by the productivity of domestic capital in period 2. Ceteris paribus, an increase in interest rate of the second period leads to a decline in the the first period consumption through inter-temporal substitution effect. To make the comparison between the cases of open and closed capital market meaningful, the first period interest rate for the closed capital market is set to be equal to international interest rate, $r^\star$.

Private basket of consumption consists of the T-sector and N-sector final goods with a Cobb-Douglas functional form:

$$\bar{C}_t(c_{N,t}, c_{T,t}) = c_{T,t}^{\gamma_c} c_{N,t}^{1-\gamma_c}$$

[6]In this maximization problem wage and interest rate are given to the households. As it will be shown later, the total consumption in t affects the economic productivity in $t+1$ through LBD effect. Since the households are atomistic, they don not internalize this effect in their inter-temporal maximization problem.

Subscripts N and T refer to N-sector and T-sector respectively. γ_c represents the intensity of consumption with respect to the T-sector. Setting the price of the T-sector products as numeraire ($P_{T,t} = 1$), the price of the N-sector final goods represents the real exchange rate ($RXR = \frac{P_{N,t}}{P_{T,t}} = P_{N,t}$). For a given relative price (real exchange rate), the household allocates his consumption expenditure between the T-sector and N-sector final goods to minimize his cost for a given consumption level ($\bar{C}$):

$$\min_{\{c_{N,t},c_{T,t}\}} \{P_{N,t}c_{N,t} + c_{T,t}\}$$
$$\text{subject to: } \bar{C}_t\left(c_{N,t}, c_{T,t}\right) = c_{T,t}^{\gamma_c} c_{N,t}^{1-\gamma_c}$$

This minimization problem leads to the following results:

$$c_{N,t} = \left(\frac{\gamma_c}{1-\gamma_c}\right)^{-\gamma_c} P_{N,t}^{-\gamma_c}\bar{C}_t \tag{2.4}$$
$$c_{T,t} = \left(\frac{\gamma_c}{1-\gamma_c}\right)^{1-\gamma_c} P_{N,t}^{1-\gamma_c}\bar{C}_t \tag{2.5}$$
$$\bar{P}_{C,t} = \frac{1}{\gamma_c^{\gamma_c}\left(1-\gamma_c\right)^{1-\gamma_c}} P_{N,t}^{1-\gamma_c} \tag{2.6}$$

With other things constant, if the total private demand increases, the demand in both sectors will increase. Moreover, an increase in the real exchange rate implies an increase in the relative demand for T-sector goods and vice versa. Finally, an appreciation of real exchange rate leads to the higher consumption price level (in terms of the T-sector final goods). This equations also can show an important source of externality in this model. An increase in the demand for the N-sector goods leads to de-industrialization which has adverse effect on productivity. Households, while deciding about their basket of consumption, do not internalize this effect.

2.2.2 Production

In each sector, firms hire labor and capital to produce final goods. I will assume a Cobb Douglas production function in both sectors:

$$F^j(K_{j,t}, L_{j,t}) = a_{j,t} K_{j,t}^{\alpha_j} L_{j,t}^{1-\alpha_j} \quad j \in \{N, T\} \tag{2.7}$$

a_t ,$K_{j,t}$ and$L_{j,t}$ represent respectively technology-level (or productivity level), private capital and labor employed in sector j at time t. α_j is the capital intensity of sector j. Note that in the case of open capital market, $K_{j,t}$ can be partially or entirely foreign investment in the domestic economy. Moreover, following Lartey (2008), I assume that a unit of T-sector good can be costlessly transformed into a unit of private capital. Consequently, the T-sector good is either consumed, or used for private and public capital formation or exported, whereas, the N-sector good is used only for consumption purposes or for public investment.

I assume that each household supplies inelastically one unit of labor in each period, $L_{T,t} + L_{N,t} = 1$. The representative firm's profit maximization problem implies that in equilibrium:

$$w_t = \frac{\partial F^T}{\partial L_{T,t}} = P_{N,t} \frac{\partial F^N}{\partial L_{N,t}} \tag{2.8}$$

$$r_t = \frac{\partial F^T}{\partial K_{T,t}} = P_{N,t} \frac{\partial F^T}{\partial K_{N,t}} \tag{2.9}$$

To make the model theoretically traceable and to focus on the mechanisms of our interest, I assume that the both sectors have the same capital intensity ($\alpha_T = \alpha_N$).[7] This assumption has two important implications which make the model much simpler and theoretically traceable: (i) both sectors have the same capital intensity which is equal to the capital intensity of the economy. (ii) In equilibrium real exchange rate and, thus aggregate price level, depend only on the ratio between the sectoral technology levels and it is independent from the foreign aid. This results is consistent with Torvik (2001) which argues that beyond very short term, when capital and labor are reallocated the impact of windfall income (here, foreign aid) on real exchange rate is negligible.[8] Formally:

Assumption 1. *I assume that the two sectors have the same capital intensity ($\alpha_T = \alpha_N$). This assumption implies that:*

$$\frac{K_{T,t}}{L_{T,t}} = \frac{K_{N,t}}{L_{N,t}} = K_t \tag{2.10}$$

$$P_{N,t} = \frac{a_{T,t}}{a_{N,t}} \tag{2.11}$$

2.2.3 Technological progress

Technology/productivity, $a_{j,t}$, is subject to endogenous progress due to both public investment and LBD effect. Public investment

[7] Inter-sectoral difference in capital intensity has important consequence specially when one compare the effect of capital market openness (See Ismail K. (2010) as an example). The implications of inter-sectoral heterogeneity in capital intensity is explained in Discussion.

[8] Note that the aim of this paper is the impact of aid on long-term growth. The impact of real exchange rate matters only in short-run. Therefore, abstracting variations in real exchange rate does not bear cost on the aim of this paper.

boost the technological/productivity progress by improving infrastructures (namely, energy, roads, water supply and telecommunication) or promoting *R&D*. Contrary to Agénor et al. (2008) and similar to Adam and Bevan (2006), in this model, public investment boosts the productivity of the economy and it is not a factor of production. For the sake of simplicity and to focus on the objective of this paper, I assume that public investment has no sectoral bias.[9]

Following the studies in the Dutch disease and the LBD externality, the T-sector is assumed to be the engine of technological progress. In fact the main source of endogenous technological progress is manufacturing sector (see for example McMillan and Rodrik (2011), Sachs and Warner (1995), Van Wijnbergen (1984)). The impact of manufacturing and modern export sectors on growth is also mentioned in the literature on undervaluing the currency-growth relationship. For example, Rodrik (2008) argues that undervaluation of currency has positive impact on growth by expanding the T-sector. Sachs and Williamson (1985) after examining the different outcomes in Latin America and East Asia conclude that the more important differences between the two set of countries are exchange rate and trade regimes which expand the tradable sector in East Asia. Dollar (1992) and Balassa (1978) also demonstrate that managing real exchange rate to encourage export and outward-oriented policies can foster growth. Consequently, in this model, de-industrialization leads to lower technological progress. To focus on the mechanisms of interest, I assume also that the LBD effect is fully spilled-over from T-sector to N-sector and, hence, the firms in both sectors will experience the same technological progress

[9]In discussion I will explain how the effect of public investment may change if its impact on productivity is biased. See also Adam and Bevan (2006).

induced by LBD externality.[10] Therefore, technological progress follows the following form:

$$\frac{a_{j,2}}{a_{j,1}} = H(L_{T,1}, \frac{g_1}{Y1}) \quad j \in \{T, N\} \tag{2.12}$$

Where $H'_{L_T} > 0$, $H'_g > 0$.

H'_g represents the quality of public investment and H'_{L_T} is the importance of the LBD effect. The magnitude of H'_g depends on the efficiency of public sector in managing the windfall revenue. The magnitude of H'_{L_T} depends on to what extend the tradeable sector is the source of endogenous growth. It is important to clarify that if the T-sector share of manufacturing is higher (compared to handicrafts and agriculture for example), H'_{L_T} is higher. As it is shown later, Y_1 (GDP in the first period) in equation (2.12) is a constant number and does not have any effect on the results. However, it can simplify the analytical resolution of the model.

Full spillover of the LBD effect and public investment implies that both sectors will realize the same technological change $\frac{a_{T,t}}{a_{N,t}} = \frac{a_T}{a_N}$. This assumption together with the assumption that both sectors have the same capital intensity lead to the following important result: relative prices and, hence, the real exchange rate will not vary with time ($P_{N,t} = \bar{P}_N = \frac{a_T}{a_N}$). Thus, the price level of basket of consumption is constant and depends only on sectoral consumption intensity $\bar{P}_C = \frac{1}{\gamma_c^{\gamma_c}(1-\gamma_c)^{1-\gamma_c}} P_N^{1-\gamma_c}$. Constant and exogenous real exchange rate significantly simplifies the model and makes it analytically traceable.

[10] In discussion, I will explain how the effect of aid may change if the LBD effect is sectoral-biased. See also Torvik (2001) for a review on LBD externality and its spill-over between the sectors.

The implications of this assumption are embodied in the following lemma:

Lemma 1. *Assuming full inter-sectoral spillover of technological progress, together with the assumption of the same inter-sectoral capital intensity imply that:*

- *Real exchange rate is constant:* $P_{N,t} = P_N = \frac{a_{T,t}}{a_{N,t}}$.
- *Production value (in terms of T-sector price level) depends only on internal capital and economy productivity level and not on the market share of the sectors.*

$$\begin{aligned} Y_t := GDP_t &= P_N a_{N,t} K_{N,t}^{\alpha} L_{N,t}^{1-\alpha} + a_{T,t} K_{T,t}^{\alpha} L_{T,t}^{1-\alpha} = a_{T,t} K_t^{\alpha} \\ &= P_N a_{N,t} K_t^{\alpha} \end{aligned} \tag{2.13}$$

- *wage depends only on the aggregate capital in the economy and on the economy technology level. More precisely, the wage will not depend on the economic share of each sector:*

$$w_t = (1-\alpha) a_{T,t} K_t^{\alpha} = (1-\alpha) P_N a_{N,t} K_t^{\alpha} = (1-\alpha) Y_t \tag{2.14}$$

- *In the case of closed capital market, interest rate depends only on aggregate capital and the T-sector technology level and it is independent from the sectoral market shares.*

$$r_t = (\alpha) a_{T,t} K_t^{\alpha-1} = (\alpha) P_N a_{N,t} K_t^{\alpha-1} = (\alpha) \frac{Y_t}{K_t} \tag{2.15}$$

- *In the case of open capital market, the internal capital depends on the T-sector technology level and it is independent from sectoral* *market shares.*

$$K_t = (\frac{\alpha a_{T,t}}{r^\star})^{\frac{1}{1-\alpha}} \tag{2.16}$$

Proof. All the proofs are resulted directly from equations (2.9), (2.8) and the implications of the assumptions that $P_N a_{N,t} = a_{T,t}$ and $\alpha_T = \alpha_N = \alpha$. □

2.2.4 The government

The government receives foreign aid in the first period. As discussed earlier, I assume that the government privatizes all its services and compensates agents by direct transfer. Therefore, the government can allocate its windfall revenue from foreign aid (A_t) between transfer to the households (TR_t) and public investment (g_t). Therefore, the government's budget constraint is:

$$TR_1 + P_{g,1} g_1 = A_1 \tag{2.17}$$

$P_{g,1}$ is the price level of the basket of public good. Note that the possibility of public investment in foreign assets and smoothing the aid, is not considered in this model. There are two reasons for excluding this policy dimension. First, the focus of this paper is on growth and the model includes only two periods. Associating the aid to the second period does not have any impact on growth and so it is not interesting for the aim of this paper. Second, the recipient governments usually do not have the option of saving the aid on foreign reserves. Nevertheless, donors can take into account this policy and choose the optimal time-pattern of aid allocation. Matsen and Torvik (2005) considering infinite horizon model and taking to account the LBD effect and Dutch disease impact of windfall income, address this question. They conclude that "the optimal share of windfall income consumed in each period needs to be adjusted down. However, a positive fraction of the resource wealth should be consumed in each period: some Dutch disease is always optimal" (Matsen and Torvik (2005)). Even though this policy is not the focus of this paper, it is worth mentioning that always donors can optimize the performance of the aid by looking at the the optimal time allocation of the aid. Such time-allocation can internalize the externality arisen by the LBD effect. This policy dimension is not the focus of the paper but it can be an interesting extension for the framework suggested by this paper.

To build one unit of technology-enhancing public good, the government must combine costlessly final goods from the T-sector and the N-sector. I assume that the basket of expenditure has Cobb-Douglas functional form: $g_t = g_{T,t}^{\gamma_g} g_{N,t}^{1-\gamma_g}$. γ_g represents the intensity of public good provision with respect to T-sector final goods. Thus, for the given inter-sectoral relative prices, the government allocates its resource between final goods from the T-sector and the N-sector to minimize the cost of providing a given amount of public investment (g_t):

$$\min_{\{g_{N,t}, g_{T,t}\}} \{P_{N,t} g_{N,t} + g_{T,t}\} \tag{2.18}$$

$$\text{subject to: } g_t = g_{T,t}^{\gamma_g} \, g_{N,t}^{1-\gamma_g} \tag{2.19}$$

This static minimization problem results in:

$$g_{T,t} = \left(\frac{\gamma_g}{1-\gamma_g}\right)^{1-\gamma_g} P_{N,t}^{1-\gamma_g} g_t \tag{2.20}$$

$$g_{N,t} = \left(\frac{\gamma_g}{1-\gamma_g}\right)^{-\gamma_g} P_{N,t}^{-\gamma_g} g_t \tag{2.21}$$

$$\bar{P}_{g,t} = \frac{1}{\gamma_g^{\gamma_g}\left(1-\gamma_g\right)^{1-\gamma_g}} P_{N,t}^{1-\gamma_g} \tag{2.22}$$

Since $P_{N,t} = \frac{a_T}{a_N}$ is constant, $\bar{P}_{g,t}$ will not vary in time and will depend only on γ_g and the initial relative technology level: $\bar{P}_{g,t} = \bar{P}_g = \frac{1}{\gamma_g^{\gamma_g}(1-\gamma_g)^{1-\gamma_g}} \bar{P}_N^{1-\gamma_g}$.

2.2.5 Market Clearing:

Market clearing implies that total expenditure (private consumption and public investment) plus private saving equal to GNP plus foreign aid. Note that private saving is $\tilde{K}_{t+1} - \tilde{K}_t$. Assuming perfect competition, GNP is $r_t\tilde{K}_t + w_t$. Thus, market clearing implies:

$$\bar{P}_{C,t}C_t + \bar{P}_{G,t}g_t + (\tilde{K}_{t+1} - \tilde{K}_t) = r_t\tilde{K}_t + w_t + A_t \tag{2.23}$$

Note that a unit of private capital is transformation of a unit of T-sector good. Therefore, the price of capital equals to the price of T-sector which is the numeraire. Moreover, in the case of open capital market, the more capital is invested by foreigners in the economy (more positive capital account), the more is the trade deficit (since more capital good should be imported). In fact $\Delta K_{t+1} - \Delta\tilde{K}_{t+1}$ is the net inflow of non-sovereign capital. In liberalized capital market, $\tilde{K}_t$ can be negative which implies that the households at time t are indebted to the rest of the world and they must repay their debts in the following periods.

By definition, total (private and public) expenditure from the N-sector equals to the total production in the same sector:

$$c_{N,t} + g_{N,t} = \frac{Y_{N,t}}{P_N}$$

Where $Y_{N,t}$ is the production value in the N-sector. On the one hand, by substituting $C_{N,t}$ and $g_{N,t}$ from equation (2.4) and (2.20), and on the other hand, knowing that: $Y_{N,t} = P_N a_{N,t} L_{N,t} (\frac{K_{N,t}}{L_{N,t}})^\alpha = a_{T,t} L_{N,t} {K_t}^\alpha$, we have:

$$\eta_c C_t + \eta_g g_t = \frac{a_{T,t} L_{N,t} {K_t}^\alpha}{P_N} = \frac{L_{N,t} Y_t}{P_N}$$

where $\eta_i = \left(\frac{1-\gamma_i}{\gamma_1}\right)^{\gamma_i} P_N^{-\gamma_i}$, for $i \in \{g, c\}$. Therefore:

$$L_{T,t} = 1 - \frac{P_N(\eta_c C_t + \eta_g g_t)}{Y_t} \tag{2.24}$$

Equation (2.24) implies that, for a given value of production, an increase in aggregate consumption (by foreign aid or other types of windfall income) leads to de-industrialization: reallocation of capital and labor to the N-sector. This de-industrialization will mitigates the technological progress as long as the T-sector is the engine of LBD.

2.2.6 Equilibrium

In this subsection, I will introduce the equilibrium of the model for two cases of closed and open capital market.

Equilibrium for the case of closed capital market

If the capital market is closed, $\tilde{K}_t = K_t$. Therefore, from equation (2.13), GDP in the first period is given ($Y_1 = a_{T,1}K_1^{\alpha}$) and the second period GDP depends on households saving in the first period and technology level in the second period:

$$Y_2 = a_{T,2}K_2^{\alpha} \tag{2.25}$$

From equation (2.15), since a_1 and K_1 are given, interest rate in the first period is given as ($r_1 = a_{T,1}\alpha K_1^{\alpha-1}$). The interest rate in the second period depends, however, on the productivity level in the second period as well as on the households saving in the first period.

$$r_2 = a_{T,2}\alpha K_2^{\alpha-1} = \alpha\frac{Y_2}{K_2} \tag{2.26}$$

Equation (2.14) implies that the wage in the first period is given ($w_1 = a_{T,1}(1-\alpha)K_1^{\alpha-1}$) and the wage in the second period depends on technological level and capital in the second period:

$$w_2 = (1-\alpha)a_{T,2}K_2^{\alpha} = (1-\alpha)Y_2 \tag{2.27}$$

Using the saving rule (equation (2.3)) and the household's intertemporal budget constraint, we have:

$$C_1 = \frac{1}{\bar{P}_C(1+\beta)}\left((1+r_1)K_1 + w_1 + TR_1 + \frac{w_2}{1+r_2}\right) \tag{2.28}$$

Finally, using the households budget constraint (equation (2.2))in the first period we find K_2:

$$K_2 = (1+r_1)K_1 + w_1 + TR_1 - \bar{P}_C C_1 \tag{2.29}$$

Now we can define the equilibrium for the closed capital economy.

Definition 1. Equilibrium in the economy with closed capital market.
For a given foreign aid in the first period $\{A_1\}$ *and given the government's policies* $\{g_1, TR_1\}$*, and predetermined variables* $\{\tilde{K}_1, a_{T,1}, a_{N,1}\}$*, the unique general equilibrium for the closed capital market economy is characterized by the vector of wage and interest rate in the second period* $\{r_2, w_2\}$*, Consumption and the labor share of the T-sector in the first period* $\{C_1, L_{T,1}\}$ *and aggregate domestic capital, technology level and GDP in the second period* $\{K_2, a_{T,2}, Y_2\}$ *such that:*

(i) Firms allocate their resources to maximize their profits (equations (2.26) *and* (2.27) *hold).*
(ii) The households decide about consumption and saving in the first period (equations (2.28) *and* (2.29) *hold).*
(iii) Market clearing in N-sector holds (equation (2.24) *holds).*
(iv) Technology evolves according to public investment and labor share of the T-sector (equation (2.12) *holds). (v) GDP in terms of T-sector* ($Y-2$) *price is determined by technology level and domestic capital (equation* (2.25) *holds).*

This leads to six equations and six endogenous variables ($\{r_2, w_2, L_{T,1}, C_1, K_2, a_{T,2}, Y_2\}$). Once C_1 and r_2 are determined, C_2 can be easily found by saving rule (equation (2.3)).

Equilibrium for the case of open capital market

If the capital market is open, the domestically used capital (K_t) and wage rate (w_t), depend only on exogenous interest rate ($r^{\star}$) and technology level ($a_{T,t}$). Since technology in the first period is given, by equations (2.15) and (2.14), wage and domestically used capital in the first period are given ($K_1 = (\frac{a_{T,1}\alpha}{r^\star})^{\frac{1}{1-\alpha}}$ and $w_1 = a_{T,1}(1-\alpha)K_1^{\alpha-1}$). The capital, production and wage in the second period depend on technical progress which is resulted from the government investment and labor share of T-sector in the first period:

$$Y_2 = a_{T,2}K_2^\alpha \tag{2.30}$$

$$K_2 = (\frac{a_{T,2}\alpha}{r^\star})^{\frac{1}{1-\alpha}} \tag{2.31}$$

$$w_2 = a_{T,2}(1-\alpha)K_2^\alpha = (1-\alpha)Y_2 \tag{2.32}$$

Notice that in this case, the wage and domestically used capital in the second period do not depend on households saving in the first periods. More precisely, wage depends on the the second period technology level and capital which itself depends on the technology level. Thus, if the capital market is open, a higher technology level in the second period leads to higher wage and capital in that period for whatever level of saving in the first period.

Similar to the case with closed capital market, consumption in the first period can be found by using the saving rule (equation (2.3)) and the household's inter-temporal budget constraint:

$$C_1 = \frac{1}{\bar{P}_C(1+\beta)}\Big((1+r^\star)\tilde{K}_1 + w_1 + TR_1 + \frac{w_2}{1+r^\star}\Big) \tag{2.33}$$

Notice that in this case, interest rate is always exogenous and equal to international interest rate. Thus, $\frac{C_2}{C_1}$ is exogenous and constant (from (equation (2.3)). Using the household's budget constraint (equation

(2.2))in the first period we find $\tilde{K}_2$:

$$\tilde{K}_2 = (1 + r^\star)\tilde{K}_1 + w_1 + TR_1 - \bar{P}_{\bar{C}}\bar{C}_1 \tag{2.34}$$

Therefore, using the technological progress rule, and sectoral labor share rule we can define the equilibrium for the economy with open capital market:

Definition 2. Equilibrium in the economy with open capital market.

For a given foreign aid in the first period $\{A_1\}$ and given the government's policies, $\{g_1, TR_1\}$, and predetermined variables $\{\tilde{K}_1, a_{T,1}, a_{N,1}\}$, the unique general equilibrium for the economy is characterized by the vector of wage , domestically owned capital, domestically used capital, technology level in the second period $\{w_2, \tilde{K}_2, K_2, a_{T,2}\}$, Consumption and labor share of the T-sector in the first period $\{C_1, L_{T,1}\}$ such that:

(i)Firms allocate their resources to maximize their profits (equations (2.31) *and* (2.31) *hold).*
(ii)The households optimize their inter-temporal utility (equations (2.33) *and* (2.34) *hold).*
(iii)Market clearing in the N-sector holds (equation (2.24) *holds).*
(iv)Technology evolves according to public investment and labor share of the T-sector (equation (2.12) *holds). (v) GDP in terms of T-sector* $(Y-2)$ *price is determined by technology level and domestic capital (equation* (2.30) *holds).*

This leads to six equations and six endogenous variables: $\{w_2, L_{T,1}, C_1, K_2, \tilde{K}_2, a_{T,2}\}$. Once C_1 is determined, C_2 can be easily found as: $C_2 = \beta(1 + r^\star)C_1$.

2.3 Macroeconomic impacts of transferred-aid

In this section I focus on the macroeconomic impacts of transferred-aid in two cases of open and closed capital market. To do so, I assume that initial aid received by the economy is A_1. $s(< 1)$ is the share of initial aid used for financing public technology-enhancing public goods and $1 - s(< 1)$ is the share transferred to the households. The economy receives the extra positive aid (dA) whose value in percentage of initial aid is $\hat{A}_1(> 0)$. In this subsection I assume that all this extra aid is transferred to households: *transferred-aid*. Thus: $(\hat{g}_1 = 0$ and $TR_1\hat{TR}_1 = A_1\hat{A}_1)$. In this case, the windfall income from the extra foreign aid has no direct impact on the technology since it is used for non-productive expenditures. However, I will show that indirectly and through the Dutch disease phenomenon, it leads to a shrinkage of the T-sector and, hence, through the LBD externality, it leads to a lower technological level in the second period. The mechanism is as follows:

Windfall income from the foreign aid which is transferred to households increases the total demand for consumption (equation (2.23)): the demand in both sectors will increase. The excess demand in the T-sector leads to more import from the rest of the world. However, by definition, it is not possible to import N-sector final goods. Thus, in short run the price in the N-sector will increase. Consequently, the marginal productivity and, hence, the return to labor and capital will increase in the N-sector. The production factors will be reallocated from the T-sector to the N-sector till, in the equilibrium, the sectoral relative prices remain unchanged. Thus, the first period share of capital and labor in the T-sector will decrease (equation (2.24)). As long as the T-sector is the engine of technical progress, technology level in the second period will be deteriorated (equation (2.12)). In the two following subsections, I explain how the macroeconomic impacts of transferred-aid can be different depending on whether the capital market is closed or open.

2.3.1 The macroeconomic impacts of transferred-aid in an open capital market economy

As explained before, transferred-aid decreases the technological progress through the Dutch disease and the LBD externality. The decline in technology level of the second period reduces the return to capital. If the capital market is open, the lower return to capital leads to capital outflow to keep the return to capital equal to international interest rate. Thus, GDP and wage in the second period will fall through (i) the decline in technology and (ii) through the outflow of capital. Households expecting a lower wage in the second period and receiving some transfers from government in the first period, will save more. Therefore, private saving will increase, even though, the domestic capital shrinks. Notice that, since interest rate is fixed internationally, $\frac{C^o{}_2}{C^o{}_1}$ remains constant.[11] Therefore, consumption in both period will increase. Consequently, the impact on welfare is always positive in this case even though the effect on growth is negative. Proposition 1 summarize formally these results.

[11]Superscripts o and c represent open and closed capital markets respectively.

Proposition 1. *When extra aid is untied ($\hat{g}_1 = 0$ and $TR_1\hat{TR}_1 = A_1\hat{A}_1 > 0$), and the capital market is open, then:*

$$\hat{C}_1^{o,u} > 0, \quad \hat{K}_2^{o,u} < 0, \quad \hat{L}_{T,1}^{o,u} < 0, \quad \hat{a}_{T,2}^{o,u} = \hat{a}_{N,2}^{o,u} < 0, \quad \hat{Y}_2^{o,u} = \hat{w}_2 < 0 \tag{2.35}$$

Proof. See Appendix A.1. □

2.3.2 The macroeconomic impacts of transferred-aid in a closed capital market economy

Similarly, once the capital market is closed, the decline in the market share of the T-sector, induced by the Dutch disease impact of transferred-aid, leads to a lower technological progress. At the same time, the households will increase their saving to smooth their consumption. Therefore, contrary to the case of open capital market, the surge in private saving accelerates the accumulation of domestic capital. Consequently, the interest rate in the second period will decrease because of both higher accumulation of capital and lower technological progress. The decline in the second period interest rate intensifies the increase in the first period consumption, through inter-temporal substitution effect. Thus, $\frac{Cc_2}{Cc_1}$ declines. Consequently, the private consumption in the first period will increase through (i) income revenue (more transfer from the government) and (ii) through inter-temporal substitution effect (by the decline in the second period interest rate).

In the case of closed capital market, while the impact of transferred-aid on technological progress is always negative, its impact on GDP is ambiguous. The reason is that transferred-aid leads to a higher accumulation of capital. If the LBD effect is not very important (H'_{L_T}

is low), $1-\gamma_c$ is small enough (consumption share of N-sector is small) and/or private capital is low and α is high (so the return to private capital is high), then the positive impact through the accumulation of capital dominates. Proposition 2 summarize these results.

Proposition 2. *When foreign aid is to be spent on non-productive expenditures ($A_1 = A^u = TR_1$) and capital market is closed, then:*

$$\hat{C}_1^{c,u} > 0, \quad \hat{K}_2^{c,u} > 0, \quad \hat{L}_{T,1}^{c,u} < 0, \quad \hat{a}_{T,2}^{c,u} = \hat{a}_{N,2}^{c,u} < 0, \tag{2.36}$$

and

$$\begin{aligned} \hat{Y}_2 =& \frac{r_2}{K_2}\frac{\alpha\beta - \sigma(1-\zeta)K_2}{(1+\beta-\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta} A_1\hat{A}_1 > 0 \Leftrightarrow \\ \sigma \equiv& \frac{(1-\gamma_c)H'_{L_T}}{a_{T,2}Y_1} < \frac{\alpha\beta}{(1-\zeta)K_2} \end{aligned} \tag{2.37}$$

where $\zeta = \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2 K_2}$.

Proof. See Appendix B.1. ☐

Moreover, in this case, the impact of transferred-aid on welfare can be negative even though its impact on the first period consumption is always positive. That would be the case where the negative impact of transferred-aid on productivity is very large. In this case, the negative impact of aid on productivity discourages households savings. That diminishes even more the second period production and hence, consumption. If this negative impact on second period consumption is very high, households will lose from welfare even though their first period has increased.

In summary, for both cases of open and closed capital market economies, transferred-aid leads to higher consumption (fig.(2.1,a))

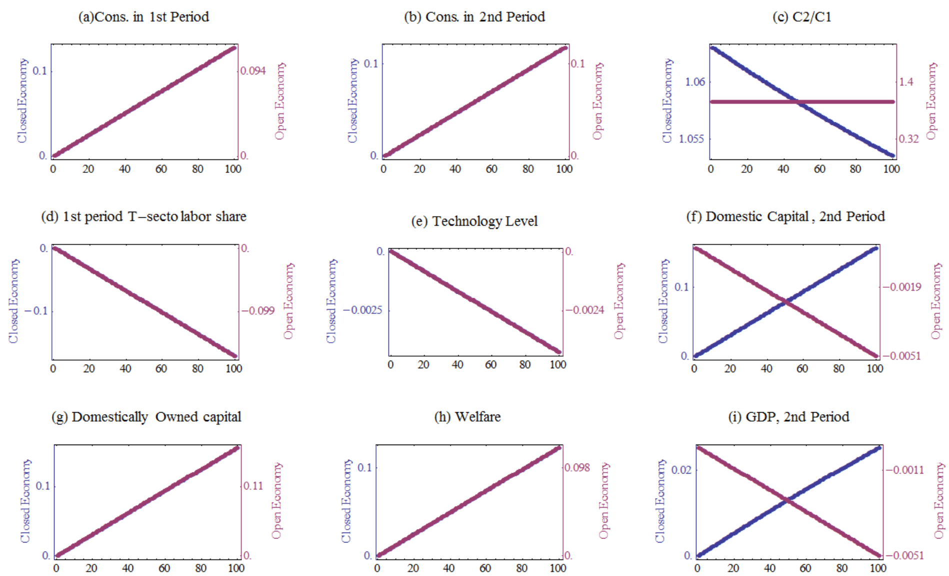


Figure 2.1: Impact of increase in transferred-aid

and saving (fig.(2.1,g)) in the first period. The increase in private consumption, financed by windfall income, leads to de-industrialization, (fig.(2.1,d)), which hinders the technological progress (fig.(2.1,e)). This impact is more pronounced when the capital market is closed. Therefore, the impact of transferred-aid on technological progress is more dreadful in this case. Nevertheless, transferred-aid leads to more domestic capital accumulation if capital market is closed, while it leads to capital outflow and so lower accumulation of domestic capital if the capital market is open (fig.(2.1,f)).

Accordingly, if the capital market is open, the impact of transferred-aid on GDP is destructive through (i) deterioration of technical progress and (ii) through outflow of capital. Hence, GNP will be always more than GDP while the impact of transferred-aid on the latter is always negative and on the former can be positive or negative. In a nutshell, transferred-aid pushes the economy with an open capital market to treat as rentiers. For the case of closed capital market, however, the impact of transferred-aid on GDP (= GNP) can be positive if the LBD effect is small, the private consumption is not very intensive to the N-sector final foods and the return ot private capital is high.

2.4 Macroeconomic impacts of invested-aid

In this section, I study the macroeconomic impacts of invested-aid for two economies with open and closed capital market. Similar to the previous section, I assume that the initial aid received by the economy is A_1. $s(< 1)$ is the share of initial aid which is used for financing public technology-enhancing public goods and $1 - s(< 1)$ is the share transferred to the households. The economy receives the extra positive aid (dA) whose value in percentage of initial aid is $\hat{A}_1(> 0)$. In this subsection, I assume that the extra aid is entirely invested in productive public goods: *invested-aid*. Thus: $\hat{g}_1 g_1 = \frac{A_1 \hat{A}_1}{P_g}$ and $\hat{TR}_1 = 0$. Since $\hat{A}_1$ is entirely tied to public investment, it has no effect on the first period budget constraint of households, however, it alters their second period budget through its influence on the second period productivity.

$\hat{A}_1$, when invested in productivity-enhancing public goods, can influence the technological progress through two different channels. On the one hand, public investment can directly boost technological progress by improving infrastructures. H'_g represents the quality of these pubic investments. On the other hand, an increase in public investment (when it is financed by foreign resources) can indirectly have a negative impact on technological progress through the Dutch disease phenomenon and the LBD effect. The fact that which impact dominates depends, on the one hand, on the efficiency and quality of the public investments (H'_g) and, on the other hand, on the magnitude of de-industrialization represented by the intensity of public goods to the N-sector ($P_N \eta_g$) and the importance of the LBD effect (H'_{L_T}). The following proposition represents mathematically the condition for which the first impact dominates.

Proposition 3. *invested-aid has positive (negative) impact on technological progress, if and only if:*

$$\hat{a}_{T,2} > 0 \Leftrightarrow H'_g > H'_{L_T} P_N \eta_g \tag{2.38}$$

Proof. See Appendix A.2 and Appendix B.2. □

In proposition 3, $P_N \eta_g$ is the magnitude of direct de-industrialization induced by an increase in externally-financed public goods.[12] This proposition let us to define *effective* and *ineffective* invested-aids as follows:

Definition 3. *Effective and ineffective invested-aids are defined as:*

(i) Invested foreign aid is **effective** *if and only if:*

$$\hat{a}_{T,2} > 0 \Leftrightarrow H'_g > H'_{L_T} \eta_g P_N$$

[12] I will show that this direct effect can influence the private consumption. The change in consumption can agitate or mitigate the de-industrialization as well.

(ii) Invested foreign aid is **ineffective** *if and only if:*

$$\hat{a}_{T,2} < 0 \Leftrightarrow H'_g < H'_{L_T}\eta_g P_N$$

If $\eta_g = 0$, the provision of public investment is only through the T-sector final goods and, hence, it does not directly induce deindustrialization. Therefore, the impact of invested-aid on the technological progress is non-negative (positive if $H'_g > 0$). In reality, however, to provide public investment, the government must employ N-sector final goods. The higher is η_g, the more likely is that invested-aid becomes ineffective. Moreover, the lower is the relative technology level of the N-sector (the higher is $\frac{a_T}{a_N} = P_N$), the more is the de-industrialization impact of invested-aid and, hence, the more likely is that the invested-aid becomes ineffective.

Note that whether or not the invested-aid is effective does not depend on the intensity of private consumption with respect to the N-sector and it does not depend on the openness of capital market. If $H'_g = H'_{L_T}\eta_g P_N$, the Dutch disease effect induced by invested-aid cancels out the positive impact of public investment on technological progress. Consequently, the productivity of economy remains unchanged. As a result, there would be no impact on private intertemporal budget constraint. Correspondingly, there would be no effect on consumption, saving and capital accumulation. In this case, the only macro effect of original aid is de-industrialization: more production in the N-sector and less production in the T-sector. Less production in the T-sector will be compensated by import which is financed by foreign aid.

However, if $H'_g \neq H'_{L_T}\eta_g P_N$, the invested-aid affects the second period budget constraint and so the first period consumption and saving. Consumption response to the second period productivity affects the productivity itself through the Dutch disease and the LBD effect. For example, if invested-aid is effective ($H'_g > H'_{L_T}\eta_g P_N$), households expecting higher revenue in the next period will increase their consumption by decreasing their saving. Higher consumption implies higher demand for the N-sector final goods which incites a reallocation of resources from the T-sector to the N-sector. The induced de-industrialization mitigates the positive effect of invested-aid on growth. The opposite holds when invested-aid is ineffective ($H'_g < H'_{L_T}\eta_g P_N$). In this case, households will decline their consumption. A lower consumption leads to a lower de-industrialization which moderates the negative impact of inefficient invested-aid on productivity. Mathematically, using equations (2.24) and (2.12), we can find:

$$\frac{da_{T,2}}{dA^T} = \frac{1}{\bar{P}_g}\frac{H'_g - P_N\eta_g H'_{L_T}}{1 + P_N\eta_c\frac{dC_1}{da_{T,2}}H'_{L_T}} \tag{2.39}$$

As it is shown in Appendix A.2 and Appendix B.2, $\frac{dC_1}{da_{T,2}}$ is always positive. Equation (2.39) implies that the more responsive is the private consumption to the next period productivity ($\frac{dC_1}{da_{T,2}}$), the higher is the consumption share of the N-sector final goods (η_c), the lower is the relative productivity in the N-sector (the higher is $\frac{a_T}{a_N} = P_N$) and the more important is the LBD externality (H'_{L_T}), the less effective is the invested-aid to boost productivity. While the impact of invested-aid on productivity follows the similar mechanisms in the two cases of open and closed capital markets, the impacts on growth are different since the response of the accumulation of domestic capital accumulation and that of private consumption with respect to invested-aid are different in the two cases of closed and open capital market. These distinctive responses are clarified in the following three subsections.

2.4.1 Impact of invested-aid in an open capital market economy

If capital market is open, private investment and, hence, accumulation of private capital do not depend on private saving; but they depend on the productivity of economy. Thus, effective foreign aid attracts foreign investment which accelerates the accumulation of domestic capital. Thus, foreign investment (capital inflow) intensifies the positive impact of invested-aid on growth. Thus, effective invested-aid boosts the GDP growth through improving the productivity of economy and, at the same time, through attracting the foreign investment. The opposite holds when invested-aid is ineffective: ineffective aid deteriorates GDP growth through (i) weakening the technological progress and by (ii) discouraging foreign investment.

Moreover, if invested-aid is effective ($H'_g > H'_{L_T}\eta_g P_N$) and it boosts the GDP growth, households, expecting higher wages in the following years, increase their first period consumption by reducing their saving. Since $\frac{C_2}{C_1}$ is constant in this case, the effect of effective invested-aid on welfare is positive. On the contrary, if invested-aid is ineffective ($H'_g < H'_{L_T}\eta_g P_N$), households, expecting lower revenue in the next period, reduce their consumption and save more. In this case, consumptions in both periods, welfare and the accumulation of capital decline These results are encapsulated in the following proposition.

Proposition 4. *If capital market is open and foreign aid is tied to public investment ($\hat{TR}_1 = 0$ and $g_1\hat{g}_1 = A_1\hat{A}_1$), then:*

- *invested-aid has positive impact on growth if and only if it is effective.*

$$\begin{aligned} \hat{Y}_2^{o,T} =& \frac{1}{1-\alpha}\hat{a}_{T,2}^{o,T} > 0 \Leftrightarrow \\ & H'_g > H'_{L_T}\eta_g P_N \end{aligned} \tag{2.40}$$

- *invested-aid leads to an increase in private consumption if and only if it is effective.*

$$\hat{C}_1^{o,T} = \hat{C}_2^{o,T} > 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.41}$$

- *invested-aid leads to an increase in households welfare if and only if it is effective.*

$$\hat{Welfare}^{o,T} > 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.42}$$

- *invested-aid improves the accumulation of capital if and only if it is effective.*

$$\hat{K}_2^{o,T} = \frac{1}{1-\alpha}\hat{a}_{T,2}^{o,T} > 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.43}$$

- *invested-aid always lead to de-industrialization whether or not it is effective.*

$$\hat{L}_{T,1}^{o,T} < 0 \tag{2.44}$$

Proof. See Appendix A.2. □

$\frac{1}{1-\alpha}$ in equation (2.45) indicates the fact that complementarity between technological progress and accumulation of domestic capital (in the case of open capital market) intensifies the impact of invested-aid on growth. In the next subsection, I show that there is negative relation between expected technological progress and accumulation of private capital if the capital market is closed. This negative relation moderates the impact of invested-aid on GDP growth for the closed capital market economy.

2.4.2 Macroeconomic impacts of invested-aid in closed capital market economy

If invested-aid is effective ($H'_g > H'_{L_T}\eta_g P_N$), the higher technology in the second period raises GDP (=GNP) and so total revenue in the second period. The increase in the inter-temporal budget of households motivates them to increase their consumption in both periods. Since the revenue in the first period is not affected by aid, the rise in the first period consumption deteriorates private saving. In the case of closed capital market the accumulation of capital depends on private saving. Therefore, higher consumption in the first period deteriorates the accumulation of private capital. Consequently, in the case of closed capital market, contrary to the case of open capital market economy, there is a negative relation between expectation of technological progress and accumulation of private capital. In other words, if the capital market is closed, an increase in public investment financed by effective invested-aid, crowds out the accumulation of private capital. The opposite holds if invested-aid is ineffective ($H'_g < H'_{L_T}\eta_g P_N$).

Moreover, higher technology level and less accumulation of capital imply a higher interest rate in the second period. Therefore, the inter-temporal relative consumption ($\frac{C_2}{C_1}$) will increase due to the effective invested-aid. In other words, the inter-temporal substitution effect crowds out partially the surge in the first period consumption and implies less de-industrialization. Higher consumption in both periods imply that effective invested aid improves the welfare. On the contrary, ineffective invested-aid deteriorates the welfare. These results are summarized formally in the following proposition:

Proposition 5. *If the capital market is closed and foreign aid is tied to public investment ($\hat{TR}_1 = 0$ and $g_1\hat{g}_1 = A_1\hat{A}_1$), then:*

- *invested-aid has positive impact on growth if and only if it is effective.*

$$\hat{Y}_2^{c,T} = \frac{(\frac{H'_g}{a_{T,2}Y_1P_g} - \sigma\chi)(1+\beta-\zeta)r_2}{(1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta} A_1\hat{A}_1 > 0 \Leftrightarrow \\ H'_g > H'_{L_T}\eta_g P_N \tag{2.45}$$

$$\textit{where:} \quad \sigma \equiv \frac{(1-\gamma_c)H'_{L_T}}{a_{T,2}Y_1} \tag{2.46}$$

- *invested-aid leads to an increase in private consumptions if and only if it is effective.*

$$\hat{C}_2^{c,T} > \hat{C}_1^{c,T} > 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.47}$$

- *invested-aid leads to an increase in households welfare if and only if it is effective.*

$$\hat{Welfare}^{c,T} > 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.48}$$

- *invested-aid improves the accumulation of capital if and only if it is* ineffective.

$$\hat{K}_2^{c,T} < 0 \Leftrightarrow H'_g > H'_{L_T}\eta_g P_N \tag{2.49}$$

- *invested-aid always lead to de-industrialization whether or not it is effective.*

$$\hat{L}_{T,1}^{c,T} < 0 \tag{2.50}$$

Proof. See Appendix B.2. □

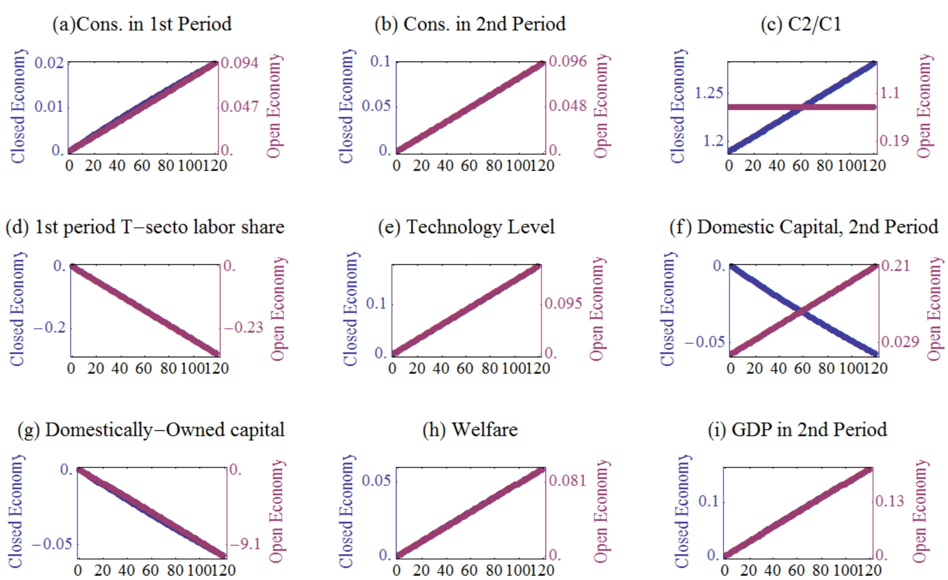


Figure 2.2: Impact of an increase in effective tied-to-investment Foreign Aid

2.4.3 Comparison between growth impacts of invested aid in closed and open capital market economies

Now we can focus on the comparison between the growth impact of effective invested-aids in two identical economies: one with open capital market and the other one with closed capital market. To make the comparison more meaningful, I assume that initially the two economies are identical in terms of technology levels, capital, consumption and other macro variables. In the case of open capital market, effective invested-aid attracts foreign investment, while in the case of closed capital market, effective invested-aid deteriorates the accumulation of private capital (fig.(2.2,f)). From this channel, invested-aid is more useful to boost the GDP growth if the capital market is open.

However, the negative LBD externality is more harmful if the capital market is open. The reason is that while interest rate is constant for open capital market economy, the interest rate in close capital market will increase as a response to effective invested-aid due to higher productivity and lower accumulation of capital. Correspondingly, inter-temporal substitution effect mitigates the increase in the first period consumption. Thus, the increase in the first period consumption is more important if the capital market is open (fig.(2.2,a)). Consequently, the de-industrialization and adverse LBD effect is more pronounced in the case of open capital market (fig.(2.2,d)). Therefore, effective invested-aid is more effective to boost technological progress if the capital market is closed (fig.(2.2,e)). From this channel, invested-aid is more effective to boost the GDP growth if the capital market is closed. These qualitative results are summarized in proposition 6

Proposition 6. *If foreign aid is invested in productivity-enhancing public goods ($\hat{TR}_1 = 0$ and $g_1 \hat{g}_1 = A_1 \hat{A}_1$) and it is effective, then:*

- *First period consumption increases more if the capital market is open.*
$$\hat{C}_1^o > \hat{C}_1^c > 0 \tag{2.51}$$

- *De-industrialization induced by invested-aid is more important if the capital market is open.*

$$\hat{L}_{T,1}^o < \hat{L}_{T,1}^c < 0 \tag{2.52}$$

- *invested-aid improves the technological progress more if the capital market is closed.*

$$0 < \hat{a}_{T,2}^o < \hat{a}_{T,2}^c \tag{2.53}$$

- *invested-aid improves (deteriorates) the accumulation of capital if the capital market is open (closed) .*

$$\hat{K}_2^c < 0 < \hat{K}_2^o \tag{2.54}$$

Proof. See Appendix B.2. □

Whether or not capital market liberalization improves the effectiveness of invested-aid depends, on the one hand, on the return to capital (the initial capital intensity of the economy (K_2) and output elasticity of capital (α)) and, on the other hand, on the magnitude of the LBD effect (H'_{L_T}) and consumption share of the N-sector products

(η_c). If the productivity of capital is high, the LBD effect generated by the T-sector is not large and the N-sector constitutes small share of private consumption, invested-aid is more effective in an economy with open capital market and vice versa.

2.5 Optimal form of foreign aid

In this section, relying on the findings in the previous sections, I study the optimal form of foreign aid in two cases of open and closed capital market economies. More precisely, I discuss which form of aid, invested-aid or transferred-aid, is more effective to boost growth in the recipient economy. These questions are addressed in this section: (i) is there the possibility that transferred-aid performs better than invested-aid? (ii) Can be a combination of the two forms brings about the optimal impact on growth? Again, the assumption is that all aid is received in the first period and the government can either invest it on growth enhancing public goods or transfer it to households. If the effect of aid is always negative, the donor will refuse to give the aid.

Optimal policy in the case of open capital market economy

In the case of open capital market, the transferred-aid is always destructive for growth due to de-industrialization and due to capital outflow (proposition 1). The invested-aid, as explained before, can boost the growth if and only if: $H'_g > H'_{L_T}\eta_g P_N$ (proposition 4). Hence, if $H'_g > H'_{L_T}\eta_g P_N$, the aid must be given in the form of invested-aid and if this condition fails to hold, no aid must be attributed to the economy. In other words, for an economy with open capital market it is never growth-enhancing to give the aid in the form of transfer to households. If $H''_{gg} < 0$, there would be a maximum limit of transferred aid which must be donated. Any extra aid more than this threshold will be destructive for growth whether it is invested or transferred.

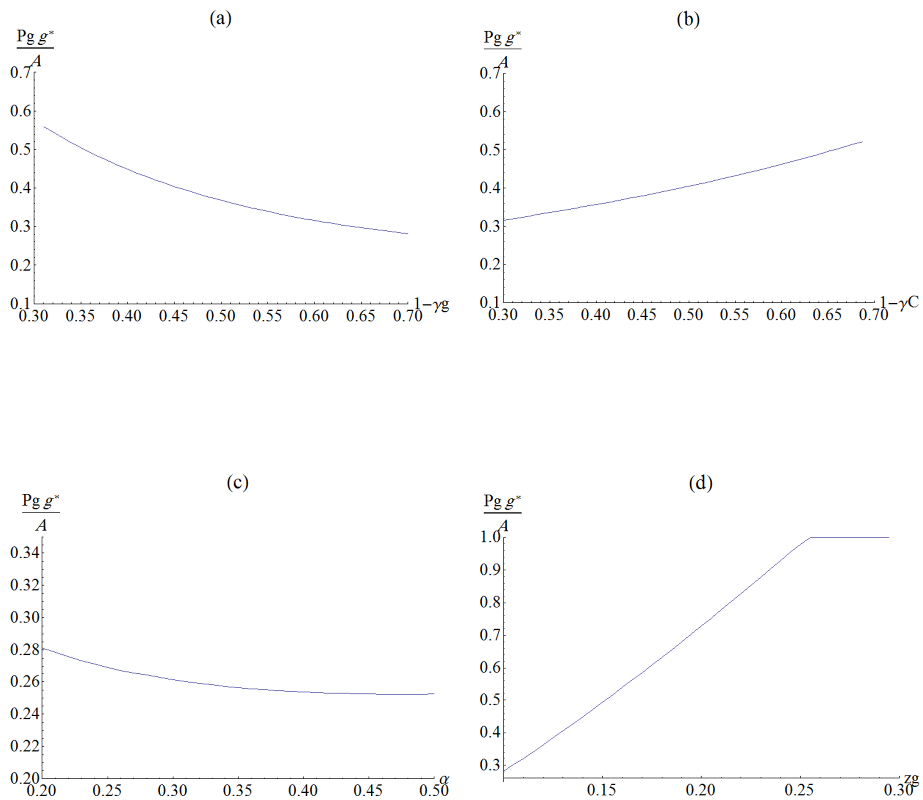
Optimal policy in the case of closed capital market economy

On the contrary, as it is embodied in proposition 2, if the capital market is closed, transferred-aid can be growth-enhancing since it encourages the accumulation of private capital. This would be the case if the accumulation of private capital dominates the negative impact of transferred-aid through de-industrialization. Invested aid can also have positive impact on growth if its positive impact on technological progress dominates its negative impact through de-industrialization ($H'_g > H'_{L_T}\eta_g P_N$). Comparing equations (2.37) and (2.45), we can result that invested-aid is better than transferred-aid for growth if and only if:

$$\hat{Y}_2^{C,T} > \hat{Y}_2^{C,U} \Leftrightarrow \quad H'_g > \delta + H'_{L_T}\bar{P}_g\Big((1-\gamma_g) - \frac{1+\zeta}{1+\beta+\zeta}(1-\gamma_c)\Big) \tag{2.55}$$

where $\zeta = \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2 K_2}$ and $\delta = \frac{\alpha\beta(a_{T,2}Y_1\bar{P}_g)}{K_2(1+\beta+\zeta)} > 0$.

Equation (2.55) implies some important policy suggestion for the structure of aid in an closed capital market economy: (i) The higher is the return to capital (high α and low K_2), the better is to donate the aid in the form of transfer to household. The intuition behind is that transferred aid always tends to increase the accumulation of private capital while the invested-aid always crowds out the accumulation of capital. Moreover, higher effectiveness of public investment (H'_g), lower share of the N-sector in public good expenditure $(1-\gamma_g)$



(a) Optimal share of invested-aid as a function of public investment share of N-sector $(1-\gamma_g)$. **(b)** Optimal share of invested-aid as a function of private consumption share of N-sector $(1-\gamma_c)$. **(c)** Optimal share of invested-aid as a function of production elasticity of capital (α). **(d)** Optimal share of invested-aid as a function of efficiency of public investment (z_g).

Figure 2.3: Optimal policy for an economy with closed capital market

and higher private consumption share of teh N-sector $(1-\gamma_c)$ push the trade-off in favor of the invested-aid. The intuition for the last two is that invested good increases mostly public expenditure whereas transferred aid always boosts private consumptions. Therefore the higher is the public expenditure share of the N-sector the more would be de-industrialization as a result of invested-aid. For the same reason, if private consumption is highly intensive to the N-sector, the de-industrialization through transferred-aid is higher. That diminishes the effectiveness of transferred aid.

Figure 2.3 represents an numerical example for these analytical results by expressing the optimal share of invested-aid in total aid ($\frac{P_g g_1^*}{A}$) as a function of different parameters. The calibration of the numerical example is reported in Appendix D appendix. Figure (2.3,(a)) shows that the higher is the intensity of public investment in N-sector final goods, less aid must be given in the form of invested-aid. Figure (2.3,(b)) implies that the higher is the consumption share of the N-sector, more aid must be attributed in the form of invested-aid. Figure (2.3,(c)) indicates that when the return to capital is high, higher proportion of aid must be taken the form of transferred-aid. Finally, figure (2.3,(d)) shows that if the quality/efficiency of public investment is high, the hgiher share of aid must be in the form of invested-aid.

In a nutshell, in an open capital market economy, the aid, if effective at all, must be always in the form of invested-aid. In the case of closed capital market economy, however, the structure of aid depends on the structure of the recipient economy. It is possible that in this case a combination of the two forms brings about the best outcome.

2.6 Discussion

2.6.1 Sectoral-bias in capital intensity

In this chapter, I assumed that both sectors have the same capital intensity ($\alpha_T = \alpha_N$). I demonstrated that this assumption implies that: (i) capital intensities of the both sectors are equal to the capital intensity of the economy and (ii) the real exchange rate and, hence, the price level depend only on the relative sectoral technology levels. Correspondingly, relaxing this assumption affects our results from two different channels.

The first channel: If the sectoral capital intensities are heterogeneous, the marginal productivity of each factor will depend on the economic share of each sector. For example, if the T-sector is relatively capital intensive, the productivity of capital (the wage) will decrease (increase) with de-industrialization of economy. Consequently, as a response to foreign aid (both tied and transferred-aids), the productivity of capital in the first period will decline, while the first period wage rate will increase (contrary to our model in which the first period wage and interest rate were unaffected by aid). Therefore, if the capital market is open, windfall income leads to capital outflow in the first period. On the contrary, if the T-sector is relatively labor intensive, foreign aid increases the first period return to capital and declines the first period wage rate. Hence, we can result that the higher is the capital intensity of the T-sector, the lower would be the effectiveness of the foreign aid. This additional channel can affect the comparison between the the effectiveness of aid in the two cases of open and capital market.

The second channel: If the two sectors have different capital intensities, the inter-sectoral relative prices will depend also on sectoral economic shares. In this case, contrary to what was demonstrated in the model, foreign aid affects the 1st period sectoral relative prices in favor of the N-sector (real appreciation of currency in the first period). Correspondingly, the 1st period aggregate price level will increase (in terms of the T-sector price level). Thus, the real value of foreign aid which is in terms of foreign currency will decline. These two channels are neglected in this chapter for the sake of having an analytical resolution and for concentrating on the mechanisms of interests.

2.6.2 Sectoral-bias in technological progress

In this paper, I assumed that the both sectors follow the same dynamic evolution. This assumption together with the assumption of symmetric capital intensity across the sectors lead to important simplifications. If this assumption is relaxed, the second period value of real exchange rate and, hence, that of the aggregate price level will change with foreign aid. However, the first period values of aggregate capital, productivity and wage remain still unaffected by aid. The change in the 2nd period exchange rate affects the the 2nd period sectoral labor shares which are unaffected by aid in the baseline model.

The change in the second period sectoral share is important if more periods of time are considered. For example, Let's assume the same model as presented here. Now we assume a three period model. Moreover, we assume that LBD effect generated in the T-sector is not spilled over to the N-sector. In this case, an aid received in the first period induces an inter-sectoral technology bias in favor of the T-sector. Therefore, in the second period the labor share of the N-sector will increase. This industrialization deteriorates the technology level of the third period.

2.7 Conclusion

The empirical studies on the linkage between aid and growth has been largely inconclusive. As mentioned by Hansen and Tarp (2000) and Chatterjee and Turnovsky (2005), this shortage is to large extent due to the lack in theoretical frameworks which would identify the mechanisms through which aid affects the macroeconomic performance of recipient economies. This paper by allowing for two dimensions of endogenous productivity growth (i.e. public investment and LBD externality), accounting for endogenous saving and, moreover, by comparing two cases of open and closed capital market, identifies new parameters and policies which influence growth-aid linkage. More precisely, this paper shows that the effectiveness of both tied and transferred-aids depend crucially upon financial market openness, the importance of LBD effect, intensity of private consumption with respect to N-sector, and, as long as invested-aid is the concern, the intensity of public investment with respect to N-sector.

Foreign aid, if it is untied and is transferred to households, leads to de-industrialization and therefore, if T-sector is the engine of LBD effect, to lower productivity growth. If capital market is open, lower productivity leads to capital outflow. Consequently, if capital market is open, transferred-aid slows down the growth of the recipient economy through de-industrialization and through lower accumulation of private capital. However, if capital market is closed transferred-aid encourage saving and, hence, accumulation of private capital. Therefore, the impact of transferred-aid on GDP growth remains ambiguous: If LBD effect is very important and private consumption is highly intensive with respect to N-sector, the negative impact through de-industrialization dominates the positive effect through accumulation of capital. The opposite holds if LBD effect is not important or consumption is largely intensive to T-sector. The paper also shows that the negative impact of aid on productivity and inter-sectoral reallocation of resource is more pronounced if capital market is closed.

The paper also investigates the relation between invested-aid and growth. the results, similar to Adam and Bevan (2006) and in contrast with Chatterjee and Turnovsky (2005) and Chatterjee et al. (2003), finds out a condition for the invested-aid to have positive impact on productivity and growth: According to our results, for given quantity of aid and for given quality of public investment, invested-aid has positive impact on growth and productivity if LBD effect of T-sector is relative low and public investment is not highly intensive to N-sector. Otherwise, invested-aid can influence negatively the productivity and growth of the recipient economy. Moreover, the results suggest that an effective invested-aid leads to more de-industrialization and less productivity growth if financial market is liberalized. Nevertheless, effective foreign aid encourages (hinders) domestic private capital if capital market is open (closed). Therefore whether or not financial liberalization must be suggested/enforced by donors to recipients depends upon the quality of public investment, the importance of LBD externality and intensity of private consumption with respect to N-sector. If public investment is efficient enough, LBD effect is relatively small and private consumption is not too intensive to N-sector, financial liberalization may enhance the effectiveness of the invested-aid. Otherwise, financial liberalization deterirates the effectiveness of the invested-aid.

This paper results in some policy suggestions: Whether aid must be in tied form or in untied form and whether financial liberalization must be a condition for aid depends, on the one hand, upon the quality of central government and public sector and, on the other hand, on the characteristics of the recipient economy. For example, if the public sector is not efficient, due to corruption, bureaucratic malfunctioning and etc., aid must be in untied form and it must be given to the recipient country only if the capital market is relatively closed. In this case, aid can be effective at least through encouraging the accumulation of private capital. On the contrary, if the government is operating well, invested-aid can help better. In this case, financial liberalization must be also suggested by donors if the LBD effect in T-sector is not very important and consumption is not very intensive to N-sector.

Appendix A: Open capital market economy

The aim of these appendices is to investigate the macroeconomic impacts of tied and transferred-aids in two economies with open and closed capital markets. For this aim, I use log-linearization method to analyze and compare the impact of an increase in aid for two economies with closed and open capital market and for two cases: (i) when the extra aid is tied and publicly invested in productivity-enhancing public goods and (ii) when the extra aid is untied and it is transferred to the households. $\hat{X}$ represents the change in variables X as a percentage of its initial value (X). For example, the initial level of foreign aid is A and $\hat{A}$ is the percentage change in the foreign aid. I assume that s is the share of A which is initially invested in productive public goods and $1-s$ is the share of the initial aid that is transferred to the households. I will show that s has no impact on our results.

In Appendix A, I investigate the macroeconomic impact of aid in an economy with open capital market. Log-linearization of the system of equations defined in definition 2 leads to the following system of equations.

$$\hat{K}_2 = \frac{1}{1-\alpha}\hat{a}_2 \tag{A.1}$$

$$\hat{w}_2 = \hat{Y}_2 \tag{A.2}$$

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(TR_1\hat{TR}_1 + \frac{w_2}{1+r^\star}\hat{w}_2) \tag{A.3}$$

$$\hat{Y}_2 = \hat{a}_{T,2} + \alpha\hat{K}_2 \tag{A.4}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T}L_{T,1}}{a_{T,2}}\hat{L}_{T,1} + \frac{H(3)}{a_{T,2}Y_1}g_1\hat{g}_1 \tag{A.5}$$

$$\hat{L}_{T,1} = \frac{-P_N}{L_{T,1}Y_1}(\eta_c C_1\hat{C}_1 + \eta_g g_1\hat{g}_1) \tag{A.6}$$

A.1: Impact of transferred-aid in an economy with open capital market.

In this subsection, I investigate the macroeconomic impact of an increase in transferred-aid for an economy with open capital market. If the extra aid is entirely transferred to households, we have:

$$TR_1\hat{TR}_1 = A_1\hat{A}_1 \tag{A.7}$$

$$g_1\hat{g}_1 = 0 \tag{A.8}$$

Using equations (A.7) and (A.8), and substituting for $\hat{w}_2$ and $\hat{K}_2$ from equations (A.2) and (A.1), we have the following system of equations.

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(A_1\hat{A}_1 + \frac{(1-\alpha)Y_2}{1+r^\star}\hat{Y}_2) \tag{A.9}$$

$$\hat{Y}_2 = \frac{1}{1-\alpha}\hat{a}_{T,2} \tag{A.10}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T}L_{T,1}}{a_{T,2}}\hat{L}_{T,1} \tag{A.11}$$

$$\hat{L}_{T,1} = \frac{-P_N}{L_{T,1}Y_1}(\eta_c C_1\hat{C}_1) \tag{A.12}$$

Using equations (A.12) and (A.11), and substituting for $\hat{C}_1$ from equation (**??**), we have:

$$\hat{a}_2 = -\frac{P_N H'_{L_T}\eta_c}{a_{T,2}Y_1\bar{P}_c(1+\beta)}(A_1\hat{A}_1 + \frac{(1-\alpha)Y_2}{1+r^\star}\hat{Y}_2) \tag{A.13}$$

Substituting for $\hat{a}_2$ from this equation into equation (A.10), we find the impact of transferred-aid on GDP.

$$\hat{Y}_2 = -\frac{(1+r^\star)P_N H'_{L_T}\eta_c}{(1-\alpha)\Big((1+r^\star)a_{T,2}Y_1\bar{P}_c(1+\beta) + P_N H'_{L_T}\eta_c Y_2\Big)}A_1\hat{A}_1 < 0 \tag{A.14}$$

Therefore, the effect of transferred-aid on growth is negative if the capital market is closed. Substituting for $\hat{Y}_2$from this equation into equation (A.9), we find the variation of private consumption to the variation in transferred-aid:

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(1 - \frac{1}{1+\mu})A_1\hat{A}_1 > 0 \tag{A.15}$$

where $\mu = \frac{(1+r^\star)a_{T,2}Y_1\bar{P}_c(1+\beta)}{P_N H'_{L_T}\eta_c Y_2} > 0$. This is the very intuitive result: households receiving windfall revenue from aid, will increase their consumption in the first period. An increase in households' windfall expenditure generates de-industrialization: $\hat{L}_{T,1} < 0$ (by equation (A.12)). De-industrialization implies reallocation of resources from productive sectors to unproductive ones. Therefore, productivity of the economy declines with aid: $\hat{a}_{T,2} < 0$ (by equation (A.11)). Lower technology level implies capital outflow: $\hat{K}_2 < 0$ (by equation (A.1)).

Impact on welfare:

Households' welfare is:

$$U(C_1, C_2) = Ln(C_1) + \beta Ln(C_2) \tag{A.16}$$

Therefore:

$$U\hat{U} = \hat{C}_1 + \beta\hat{C}_2 \tag{A.17}$$

Knowing that $C_2 = \beta(1 + r^\star)C_1$, we have:

$$U\hat{U} = (1 + \beta)\hat{C}_1 > 0 \tag{A.18}$$

Therefore, the impact of transferred-aid on households welfare of households in an economy with open capital market is always positive even though it always reduces growth.

A.2: Impact of invested-aid in an economy with open capital market.

In this subsection, similar to the previous one, I consider an economy with open capital market. However, I assume that the extra aid is invested in productive public goods: invested-aid. Thus:

$$T R_1 \hat{T R_1} = 0 \tag{A.19}$$

$$g_1 \hat{g}_1 = \frac{A_1 \hat{A}_1}{\bar{P}_g} \tag{A.20}$$

Using equations (A.19) and (A.20), and substituting for $\hat{w}_2$ and $\hat{K}_2$ from equations (A.2) and (A.1), we can rewrite equations ((A.3):(A.6)) as follows.

$$\hat{C}_1 = \frac{(1-\alpha)Y_2}{\bar{P}_c(1+\beta)C_1(1+r^\star)}\hat{Y}_2 \tag{A.21}$$

$$\hat{Y}_2 = \frac{1}{1-\alpha}\hat{a}_{T,2} \tag{A.22}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T} L_{T,1}}{a_{T,2}}\hat{L}_{T,1} + \frac{H'_g}{a_{T,2} Y_1 \bar{P}_g} A_1 \hat{A}_1 \tag{A.23}$$

$$\hat{L}_{T,1} = \frac{-P_N}{L_{T,1} Y_1}(\eta_c C_1 \hat{C}_1 + \frac{\eta_g}{\bar{P}_g} A_1 \hat{A}_1) \tag{A.24}$$

Substituting for $\hat{C}_1$ from equation (A.21) into equation (A.24), and then inserting equation (A.24) into equation (A.23), we car rewrite equation (A.23) as:

$$\hat{a}_{T,2} = -\frac{H'_{L_T} P_N \eta_c (1-\alpha) Y_2}{a_{T,2} Y_1 P_c (1+\beta)(1+r^\star)}\hat{Y}_2 + \frac{H'_g - H'_{L_T} P_N \eta_g}{a_{T,2} Y_1 \bar{P}_g} A_1 \hat{A}_1 \tag{A.25}$$

Now, by substituting for $a_{T,2}$ from equation (A.25) into equation (A.22) and solving for $\hat{Y}_2$, we can find:

$$\hat{Y}_2 = \frac{P_c}{P_g}\frac{(1+\beta)(1+r^\star)}{1-\alpha}\frac{H'_g - H'_{L_T}P_N\eta_g}{a_{T,2}Y_1\bar{P}_c(1+\beta)(1+r^\star) + H'_{L_T}P_N\eta_c Y_2}A_1\hat{A}_1 \tag{A.26}$$

Equation (A.26) implies that as long as the T-sector is the engine of productivity growth ($H'_{L_T} > 0$), untied invested-aid has positive impact on growth if and only if $H'_g > H'_{L_T}P_N\eta_g$. This implies that the positive impact of public investment in technology must dominates the negative impact of aid through de-industrialization.

From equations (A.21) and (A.22) we can result that:

$$\text{If:} \quad H'_g > (<) H'_{L_T}P_N\eta_g \Rightarrow \hat{Y}_2 > (<) 0 \Rightarrow \begin{cases} \hat{C}_1 > (<) 0 & \text{by eq. (A.21)} \\ \hat{a}_{T,2} > (<) 0 & \text{by eq. (A.22)} \\ \hat{K}_2 > (<) 0 & \text{by eq. (A.1)} \end{cases} \tag{A.27}$$

Proof for $\hat{L}_{T,1} < 0$.
We assume $\hat{L}_{T,1} > 0 \Rightarrow \hat{C}_1 < 0$ (by equ.(A.24) $\Rightarrow \hat{Y}_2 < 0$ (by equ. (A.21)) $\Rightarrow \hat{a}_{T,2} < 0$ (by equ. (A.22) $\Rightarrow \hat{L}_{T,1} < 0$ (by equ.(A.23) $\Rightarrow$ Contradiction. Thus, $\hat{L}_{T,1} < 0$.

A.3: Comparison between the growth impacts of invested-aid and transferred-aid in an economy with open capital market.

In appendices appendix A.1 and appendix A.2, we found the GDP response to untied and invested-aid. Let's represent the percentage variation of GDP to transferred-aid and invested-aid in an open capital market economy with $\hat{Y}_2^{O,U}$ and $\hat{Y}_2^{O,T}$, respectively. Form equations (A.26) and (A.14), we can find the condition for which invested-aid works better than transferred-aid in an economy with open capital market:

$$\hat{Y}_2^{O,T} > \hat{Y}_2^{O,U} \quad \text{IFF} \quad H'_g > H'_{L_T} P_N \bar{P}_g \left(\frac{\eta_g}{\bar{P}_g} - \frac{1}{1+\beta}\frac{\eta_c}{\bar{P}_c}\right) \tag{A.28}$$

Appendix B: Closed capital market economy

In Appendix B, I investigate the macroeconomic impacts of aid in an economy with closed capital market. Log-linearization of the system of equations defined in definition 1 leads to the following system of equations.

$$\hat{r}_2 = \hat{Y}_2 - \hat{K}_2 \tag{B.1}$$

$$\hat{w}_2 = \hat{Y}_2 \tag{B.2}$$

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(TR_1\hat{TR}_1 + \frac{w_2}{1+r_2}\hat{w}_2 - \frac{w_2 r_2}{(1+r_2)^2}\hat{r}_2) \tag{B.3}$$

$$\hat{K}_2 = \frac{1}{K_2}(TR_1\hat{TR}_1 - \bar{P}_c C_1 \hat{C}_1) \tag{B.4}$$

$$\hat{Y}_2 = \hat{a}_2 + \alpha\hat{K}_2 \tag{B.5}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T} L_{T,1}}{a_{T,2}}\hat{L}_{T,1} + \frac{H(3)}{a_{T,2}Y_1} g_1 \hat{g}_1 \tag{B.6}$$

$$\hat{L}_{T,1} = \frac{-P_N}{L_{T,1}Y_1}(\eta_c C_1 \hat{C}_1 + \eta_g g_1 \hat{g}_1) \tag{B.7}$$

B.1: Impact of transferred-aid in an economy with closed capital market.

In this subsection, I investigate the macroeconomic impacts of an increase in transferred-aid for an economy with closed capital market. If the extra aid is entirely transferred to households, we have:

$$TR_1 T\hat{R}_1 = A_1 \hat{A}_1 \tag{B.8}$$

$$g_1 \hat{g}_1 = 0 \tag{B.9}$$

Using equations (B.8) and (B.9), and substituting for $\hat{w}_2$ and $\hat{r}_2$ from equations (B.2) and (B.1), we can have the following system of equations.

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(A_1\hat{A}_1 + \frac{(1-\alpha)Y_2}{(1+r_2)^2}\hat{Y}_2 + \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2}\hat{K}_2) \tag{B.10}$$

$$\hat{Y}_2 = \hat{a}_{T,2} + \alpha\hat{K}_2 \tag{B.11}$$

$$\hat{K}_2 = \frac{1}{K_2}(A_1\hat{A}_1 - \bar{P}_c C_1 \hat{C}_1) \tag{B.12}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T} L_{T,1}}{a_{T,2}}\hat{L}_{T,1} \tag{B.13}$$

$$\hat{L}_{T,1} = -\frac{P_N}{L_{T,1}Y_1}(\eta_c C_1 \hat{C}_1) \tag{B.14}$$

Substituting for $\hat{K}_2$ from equation (B.12) into equation (B.10), we can find:

$$\hat{C}_1 = \frac{1}{\bar{P}_c C_1}(\frac{1+\zeta}{1+\beta+\zeta}A_1\hat{A}_1 + \frac{\zeta K_2}{(1+\beta+\zeta)r_2}\hat{Y}_2) \tag{B.15}$$

where $\zeta = \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2 K_2} < 1$.

Substituting for $\hat{C}_1$ from equation (B.15), we can rewrite equation (B.12) as:

$$\hat{K}_2 = \frac{\beta}{(1+\beta+\zeta)K_2} A_1 \hat{A}_1 - \frac{\zeta}{(1+\beta+\zeta)r_2} \hat{Y}_2 \tag{B.16}$$

Combining equations (B.14) and (B.13) we have:

$$\hat{a}_{T,2} = -\frac{H'_{L_T} P_N \eta_c C_1}{a_{T,2} Y_1} \hat{C}_1 < 0 \tag{B.17}$$

Therefore, transferred-aid has qualitatively the same impact on technological progress for closed capital market economy as in an economy with open capital market ($\underline{\hat{a}_{T,2} < 0}$). Substituting for $\hat{C}_1$ from equation (B.15) into equation (B.17), we can find the percentage variation of technology as a function of aid and GDP growth:

$$\hat{a}_{T,2} = -\frac{\sigma(1+\zeta)}{1+\beta+\zeta} A_1 \hat{A}_1 - \frac{\sigma \zeta K_2}{(1+\beta+\zeta)r_2} \hat{Y}_2 \tag{B.18}$$

where $\sigma = \frac{H'_{L_T}(1-\gamma_c)}{a_{T,2} Y_1} > 0$.

Finally substituting for $\hat{a}_{T,2}$ and $\hat{K}_2$ from equations (B.18) and (B.16) into equation (B.11), we can find GDP growth as function of the variation in transferred-aid.

$$\hat{Y}_2 = \frac{r_2}{K_2} \frac{\alpha\beta - \sigma(1+\zeta)K_2}{(1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta} A_1 \hat{A}_1 \tag{B.19}$$

This equation implies that:

$$\hat{Y}_2 > 0 \Leftrightarrow \sigma \equiv \frac{H'_{L_T}(1-\gamma_c)}{a_{T,2} Y_1} < \frac{\alpha\beta}{(1+\zeta)K_2} \tag{B.20}$$

Proof for $\hat{K}_2 > 0$.

Substituting $\hat{Y}_2$ from this equation into equation (B.16) we find:

$$\hat{K}_2 = \frac{\beta r_2 + \sigma\zeta K_2}{K_2\Big((1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta\Big)} A_1 \hat{A}_1 > 0 \tag{B.21}$$

Proof for $\hat{C}_1 > 0$.

Substituting $\hat{Y}_2$ from equation (B.19) into equation (B.15) we find:

$$\hat{C}_1 = \frac{1}{\bar{P}_c C_1} \frac{(1+\zeta)r_2 + \alpha\zeta}{(1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta} > 0 \tag{B.22}$$

Proof for $\hat{r}_2 < 0$.

From equation (B.1) and using equations (B.21) and (B.19), we have:

$$\hat{r}_2 = -\frac{(1-\alpha)r_2\beta + \sigma K_2\Big(\zeta + r_2(1+\zeta)\Big)}{K_2\Big((1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta\Big)} < 0 \tag{B.23}$$

Impact on welfare:

Households' welfare is:

$$U(C_1, C_2) = Ln(C_1) + \beta Ln(C_2) \tag{B.24}$$

Therefore:

$$U\hat{U} = \hat{C}_1 + \beta\hat{C}_2 \tag{B.25}$$

Knowing that $C_2 = \beta(1+r_2)C_1$, we have:

$$U\hat{U} = (1+\beta)\hat{C}_1 + \frac{\beta r_2}{1+r_2}\hat{r}_2 \tag{B.26}$$

There are two opposite effects on welfare: positive impact through increasing first period consumption and negative impact through reducing interest rate. Hence, the impact of transferred-aid on welfare is ambiguous. If the negative impact through productivity is very large, households expecting very low interest rate will save less. In that case, the impact on second period consumption can be negative. If this impact dominates the positive effect on first period consumption, the total impact of transferred-aid on welfare will be negative. More precisely, using equations (B.22) and (B.23), we can find:

$$U\hat{U} = \frac{K_2(1+r_2)(1+\beta)((1+\zeta)r_2+\alpha\zeta) - \beta r_2 \bar{P}_c C_1\Big((1-\alpha)r_2\beta + \sigma K_2\big(\zeta + r_2(1+\zeta)\big)\Big)}{\bar{P}_c C_1 K_2(1+r_2)\big((1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta\big)} \tag{B.27}$$

If σ (which represents the negative impact of transferred-aid on productivity) is very large, the total impact of transferred-aid can be negative.

B.2: Impact of invested-aid in an economy with closed capital market.

In this subsection, similar to the previous one, I consider an economy with closed capital market. However, I assume that the extra aid is invested in productive public goods: invested-aid. Thus:

$$TR_1\hat{TR}_1 = 0 \tag{B.28}$$

$$g_1\hat{g}_1 = \frac{A_1\hat{A}_1}{\bar{P}_g} \tag{B.29}$$

Using equations (B.28) and (B.29), and substituting for $\hat{w}_2$ and $\hat{r}_2$ from equations (B.2) and (B.1), we can rewrite equations ((B.3):(B.7)) as follows.

$$\hat{C}_1 = \frac{1}{\bar{P}_c(1+\beta)C_1}(\frac{(1-\alpha)Y_2}{(1+r_2)^2}\hat{Y}_2 + \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2}\hat{K}_2) \tag{B.30}$$

$$\hat{Y}_2 = \hat{a}_{T,2} + \alpha\hat{K}_2 \tag{B.31}$$

$$\hat{K}_2 = -\frac{\bar{P}_c C_1}{K_2}\hat{C}_1 \tag{B.32}$$

$$\hat{a}_{T,2} = \frac{H'_{L_T} L_{T,1}}{a_{T,2}}\hat{L}_{T,1} + \frac{H'_g}{a_{T,2} Y_1 \bar{P}_g} A_1 \hat{A}_1 \tag{B.33}$$

$$\hat{L}_{T,1} = \frac{-P_N}{L_{T,1} Y_1}(\eta_c C_1 \hat{C}_1 + \frac{\eta_g}{\bar{P}_g} A_1 \hat{A}_1) \tag{B.34}$$

By equations (B.32) and (B.30), we can find:

$$\hat{C}_1 = \frac{K_2}{r_2 \bar{P}_c C_1}\frac{\zeta}{1+\beta+\zeta}\hat{Y}_2 \tag{B.35}$$

$$\hat{K}_2 = -\frac{\zeta}{(1+\beta+\zeta)r_2}\hat{Y}_2 \tag{B.36}$$

Combining equations (B.34) and (B.33) and using equation (B.35), we can find the variation of technological progress as a function of GDP growth and the change in invested-aid:

$$\hat{a}_{T,2} = -\frac{\sigma\zeta K_2}{(1+\beta+\zeta)r_2}\hat{Y}_2 + (\frac{H'_g}{a_{T,2} Y_1 \bar{P}_g} - \sigma\chi)A_1\hat{A}_1 \tag{B.37}$$

where $\chi = \frac{\eta_c}{\eta_g}\frac{\bar{P}_c}{\bar{P}_g}$.

We can substitute for $\hat{K}_2$ and $\hat{a}_{T,2}$ from the last two equations into equation (B.31) to find GDP growth as a function of the variation in invested-aid:

$$\hat{Y}_2 = \frac{(\frac{H'_g}{a_{T,2}Y_1\bar{P}_g} - \sigma\chi)(1+\beta-\zeta)r_2}{(1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta} A_1\hat{A}_1 \tag{B.38}$$

This equation implies that:

$$\hat{Y}_2 > 0 \Leftrightarrow \frac{H'_g}{a_{T,2}Y_1\bar{P}_g} > \sigma\chi \Leftrightarrow H'_g > P_N\eta_g H'_{L_T} \tag{B.39}$$

equations (B.35) and (B.36) imply that:

$$H'_g > P_N\eta_g H'_{L_T} \Leftrightarrow \begin{cases} \hat{C}_1 > 0 \\ \hat{K}_2 < 0 \end{cases} \tag{B.40}$$

Moreover using equations (B.38) and (B.37) we have:

$$\hat{a}_{T,2} = \frac{(1+\beta+\zeta)r_2 + \alpha\zeta}{(1+\beta+\zeta)r_2 + \sigma\zeta K_2 + \alpha\zeta}(\frac{H'_g}{a_{T,2}Y_1\bar{P}_g} - \sigma\chi)A_1\hat{A}_1 \tag{B.41}$$

Therefore:

$$\hat{a}_{T,2} > 0 \Leftrightarrow \hat{Y}_2 > 0 \Leftrightarrow H'_g > P_N\eta_g H'_{L_T} \tag{B.42}$$

Proof for $\hat{L}_{T,1} < 0$.

Let's assume that $\hat{L}_{T,1} > 0$. Thus:

$$\text{If: } \hat{L}_{T,1} > 0 \Rightarrow \begin{cases} \hat{C}_1 < 0 \quad \text{(eq. (B.34))} \Rightarrow \hat{Y}_2 < 0 \quad \text{(eq. (B.35))} \\ \qquad\qquad \Rightarrow \hat{K}_2 > 0 \quad \text{(eq. (B.36))}. \\ \hat{a}_{T,2} > 0 \quad \text{(by eq. (B.33))}. \end{cases} \tag{B.43}$$

If $\hat{a}_{T,2} > 0$ and $\hat{K}_2 > 0$, equation (B.31) implies that $\hat{Y}_2 > 0 \Rightarrow \hat{C}_1 > 0$ (by eq. (B.35)) $\Rightarrow \hat{L}_{T,1} < 0$ (by eq. (B.34)) which is contradiction. Thus: invested-aid always lead to de-industrialization: $\underline{\hat{L}_{T,1} < 0}$.

B.3: Comparison between the growth impacts of invested-aid and transferred-aid in an economy with closed capital market.

In appendices appendix B.1 and appendix B.2, we found the GDP growth response to untied and invested-aid. Let's represent the GDP growth to transferred-aid and invested-aid in an closed capital market economy with $\hat{Y}_2^{C,U}$ and $\hat{Y}_2^{C,T}$, respectively. Form equations (B.19) and (B.38), and knowing that $\frac{\eta_i}{\bar{P}_i} = \frac{1-\gamma_i}{P_N}$ we can find the condition for which invested-aid works better than transferred-aid in an economy with open capital market:

$$\hat{Y}_2^{C,T} > \hat{Y}_2^{C,U} \Leftrightarrow \quad H'_g > \delta + H'_{L_T}\bar{P}_g\Big((1-\gamma_g) - \frac{1+\zeta}{1+\beta+\zeta}(1-\gamma_c)\Big) \tag{B.44}$$

where $\delta = \frac{\alpha\beta(a_{T,2}Y_1\bar{P}_g)}{K_2(1+\beta+\zeta)} > 0$.

C: Comparison of the impacts of foreign aid in open and closed capital market

To be able to compare the impact of invested-aid in two economies with open and closed capital market, I assume that the economies are initially identical: $r_2 = r_1 = r^\star$, $X_t^c = X_t^o$ for $t \in \{1, 2\}$ and $X \in \{K, a, LT, C\}$.

C.1: Comparison of the impacts of invested-aid in open and closed capital market economies

Comparison of First period consumption.

We assume that $\hat{C}_1^c > \hat{C}_1^o$. Therefore:

$$\text{If:}\hat{C}_1^c > \hat{C}_1^o \Rightarrow \begin{cases} \hat{L}_{T,1}^c < \hat{L}_{T,1}^o (\text{by eq. (B.34) (A.24)}) \\ \qquad \Rightarrow \hat{a}_{T,2}^c < \hat{a}_{T,2}^o (\text{by eq. (B.33) (A.23)}) \\ \hat{K}_2^c < 0 < \hat{K}_2^o (\text{by eq. (A.1) (B.32)}) \end{cases} \tag{C.1}$$

Thus: $\hat{Y}_2^c < \hat{Y}_2^o$ (by equations (B.31) and (A.4)).

For open capital market from equation (2.33) we have:

$$\hat{C}_1^o = \frac{1}{\bar{P}_C C_1(1+\beta)} \frac{(1-\alpha)Y_2}{1+r^\star} \hat{Y}_2^o \tag{C.2}$$

And for closed capital market, from equation (2.28)

$$\hat{C}_1^o = \frac{1}{\bar{P}_C C_1(1+\beta)} \left(\frac{(1-\alpha)Y_2}{1+r_2} \hat{Y}_2^c - \frac{(1-\alpha)Y_2 r_2}{(1+r_2)^2} \hat{r}_2\right) \tag{C.3}$$

Knowing that $r^\star = r_2$ and $\hat{r}_2 > 0$, $\hat{Y}_2^c < \hat{Y}_2^o$ implies that $\hat{C}_1^c < \hat{C}_1^o$ which contradicts our assumption. Therefore: $\underline{\hat{C}_1^c < \hat{C}_1^o}$.

Comparison of De-industrialization and Technological Progress.

If $\hat{C}_1^c < \hat{C}_1^o$, by equations (B.34) and (A.24) we result that $\underline{\hat{L}_{T,1}^c > \hat{L}_{T,1}^o}$. Thus by equations (B.33) and (A.23) we have: $\underline{\hat{a}_{T,2}^c > \hat{a}_{T,2}^o}$.

D: Calibration for numerical examples

All the results are shown analytically and therefore the results are not sensitive to calibration of the model. Nevertheless, in this section I report the calibration that is used in the numerical examples. The function of technological progress is defined as:

$$H(g_1, L_{T,1}) = (1 + z_L L_{T,1} + z_g \frac{g_1}{Y_1}) \tag{D.1}$$

Table 1: Calibrated parameters

Symbol	Value	Interpretation
α	0,2	Output elasticity of capital.
r^*	0.055	International interest rate.
γ_g	0.3	publ. investment elasticity of T-sector final goods.
γ_c	0.8	priv. consumption elasticity of T-sector final goods.
z_l	0.1	Importance of LBD effect in technological progress.
z_g	0.1	Efficiency of public investment.
$a_{T,1}$	1	1st period technology level in T-sector.
$a_{N,1}$	1	1st period technology level in N-sector.
β	0,8	Discount factor.
K_1	8	Initial domestic capital.
L_1	1	Inelastic labor supply.

Chapter 3

The political economy of twin deficits and wage bargaining centralization

Abstract

This paper contributes to the literature on current account imbalances. Econometric analysis of the paper finds evidence that wage centralization, in a cross-section of industrialized economies, is significantly associated with lower deficits in current account and budget balance (the twin deficits). To explain this empirical finding, the paper provides a political economy framework in which the government follows preferences of non-tradeable-sector (N-sector) workers who represent the majority. An increase in the twin deficits by issuing external public debt leads to real appreciation of the currency. As between-sector mobility is constrained by friction in the labor market, wages in N-sector rises. Thus, N-sector workers relatively support (oppose) more a rise (reform) in the two deficits. Centralization of wage bargaining moderates the benefit and costs from such twin-deficit policies by reducing the responsiveness of sectoral wage with respect to sectoral prices. Thus, the more centralized is the wage determination, the less N-sector workers support (oppose) a rise (reform) in the two deficits. Correspondingly, more centralized wage bargaining reduces the government's political incentive (cost) to deteriorate (reform) the external balance through the fiscal balance.
Keywords: Twin deficits, Current account imbalances, Dutch disease, Search and Match, Wage bargaining Centralization, Real Exchange rate.

JEL-Classification: F32, E62, J31, J51, J6, F41.

3.1 Introduction

Global current account imbalances have been focal points of interest in international macroeconomics, especially since the financial crisis in 2007/2008. Many authors argued that the global imbalances and the global financial crisis are intimately connected (see for example Obstfeld and Rogoff (2009) and Caballero and Krishnamurthy (2009)). The crucial importance of the subject in policy-oriented debates motivated theoretical and empirical researches to identify the fundamental determinants of global current account patterns. The related literature generally find that the saving glut in fast-growing emerging markets and in oil countries as well as financial, institutional and macro variables can, to large extent, account for observed global current account imbalances. According to the existing literature these variables include budget balance, financial development, demographic variables, stage of development, terms of trade volatility and previously accumulated foreign reserves.

This paper provides a new contribution to this literature by studying the relationship between wage centralization and observed current account imbalances among industrial economies. The empirical results of this paper demonstrate that higher wage centralization is significantly and positively associated with current account balances in the cross-section of advanced economies. Besides, the evidence from panel data for 16 OECD countries and over the period 1980-2012 suggests that this link is, to a large extent, through a positive correlation between wage centralization on public savings (budget balance), whereas no evidence is found for the relationship between wage centralization and households savings (the other competent of national saving).

I find robust evidence that wage centralization is associated with higher budget balance in the cross-section of industrial economies. This positive linkage is an important contribution to the literature and to policy-oriented discussions on current account imbalances, given the twin deficits hypothesis. This hypothesis has been studied by a large number of theoretical and empirical papers (see for example Chinn et al. (2014) and Chinn and Ito (2007)). Empirical studies generally suggest that 1% increase in fiscal deficit leads to around $0.1\% - 0.3\%$ increase in current account deficit.[1] In the aftermath of 2007/2008 financial crisis, many countries faced the challenge of preventing the reemergence of large current account deficits through reducing fiscal deficits. Budget balance is one of the most direct instruments for governments to control external balances (Chinn (2005)). Hence, some crucial questions must be addressed: "why governments in industrial economies behave such differently in managing their fiscal balances and their external debts?" and "What are the determinant factors of budget balance?". This paper tries to shed some light on these questions.

The paper provides a theoretical model to explain the link between the wage centralization and the twin deficits. The mechanism relies on a political economy framework which presumes that the government uses the fiscal balance and its external debt position as a tool for preserving its office.[2] In such a framework, it is assumed that the government, when managing its balance, follows preferences of workers in non-tradeable sector (notably construction and services) who

[1]Our empirical analysis suggests the magnitude in the same range. This result suggests the existence of a significant but incomplete Ricardian effect.

[2]The role of political incentives, for managing the fiscal balance has been studied by previous literature. See for example Alesina et al. (1998) and Velasco (1999).

represent the majority in all industrial economies. I argue that wage centralization reduces the N-sector workers' thirst for widening the public external debt and their dismay for public debt reduction. This affects the political incentive of the government in managing its balance. The mechanism which is suggested by the paper is as follows:

A rise in the budget deficit, by issuing external debt, can improve the short-term aggregate welfare through tax reduction and/or increase in public good provision. At the same time, it leads to a surge in inflow of external capital (as long as the Ricardian equivalence fails to be complete). This external capital induces a symptom of Dutch disease: appreciation of real exchange rate, i.e. an increase in the relative price of the N-sector products. Therefore it would be more profitable to produce in the N-sector. Consequently, the surge in the twin deficits induces an inter-sectoral wage dispersion in favor of the N-sector, as friction in the labor market and sector-specific human capital severely constrain the between-sector labor mobility. Correspondingly, workers in the N-sector support more such twin deficits policy compared to workers in the tradeable sector, who are adversely affected by the loss in international competitiveness of their sector and by the decline in their wage (in terms of aggregate price level). For the same reason, the workers in the N-sector relatively opposed more reforms in the twin deficits.

Centralization of wage bargaining decreases this effect by reducing wage flexibility, i.e. the sensitivity of sector-specific wages with respect to sectoral prices (and hence, to changes in real exchange rate).[3] Thus,

[3] Holmlund and Zetterberg (1991), Hartog et al. (2002) and Teulings and Hartog (1998) have shown that sectoral wage dispersion, after controlling for labor-skills

the gains and losses from the twin deficits are smaller. Consequently, wage centralization moderates N-sector workers' supports for the deterioration of the two balances and their oppositions against the reform in the two deficits. Correspondingly, if the wage bargaining is more centralized, the policy maker, following N-sector workers' preferences, finds less political support for widening its external debts and also faces less political costs for improving the two balances.

To the best of my knowledge, this paper is the first attempt to study the relationship between wage centralization and current account. The impact through the budget balance is also new in the literature. Nevertheless, some other links between wage centralization and current account can be deduced by combining the findings of related literature. The most related studies are the ones on inequality-current account relationship. Kumhof et al. (2012), Behringer et al. (2013) and Marzinotto (2016) have shown that in the cross-section of industrial economies, a rise in inequality is associated with an increase in external deficit. This link is explained by the negative impact of inequality on households savings. Given the negative impact of wage centralization on personal income inequality, one can expect that wage centralization can improve the current account via encouraging households savings. Tge empirical results of this paper confirms the chain of these three linkages: inequality-current account, inequality-households savings and wage centralization-inequality. However, no significant evidence is found for a positive impact of wage centralization on households saving. This can be explained by the positive

and job conditions, and the responsiveness of the sectoral wages to sectoral prices is lower in countries with more centralized wage bargaining system. This impact of wage centralization will be discussed more precisely later.

effect of wage centralization on budget balance: the positive impact of wage centralization on public saving tends to reduce the households saving through an incomplete Ricardian effect. This negative impact offsets the positive impact of wage centralization on households savings through reducing inequality.

The rest of the paper is organized as follows: section 3.2 discusses the different strands of literature which are related to this paper. Section 3.3 discusses some historical facts related to the purpose of this paper. Section 3.4 is devoted to econometric analysis. Section 3.5 establishes the theoretical model. In section 3.6 I run a numerical analysis to demonstrate the theoretical mechanism. Finally, section 3.8 concludes. Some econometrics analysis, historical facts are reported in the appendix.

3.2 Literature review

Four strands of literature are relevant to this paper. The literature on (i) current account imbalances, (ii) wage centralization, (iii) the Dutch disease impact of windfall incomes, and finally, (iv) search and match frictional labor market.

Literature on current account imbalances

The research on current account imbalances was firstly motivated by the large current account deficit in the US starting from the 1990's. Bernanke et al. (2005) and Clarida (2005) attribute this dramatic trend in the US external balance to saving glut in Asian emerging-market countries and the oil exporters, ranging from Persian gulf countries to

Norway. In a more global point of view, this perspective may fail to explain why it is that the US, UK, Ireland and specific other advanced economies run substantial external deficits, while other industrial countries such as Germany, Nordic countries, Japan and the Netherlands have usually experienced external surpluses.

Recently, empirical papers tried to identify the possible determinants of external balance using panel regressions (see for example, Chinn and Prasad (2003), Cheung et al. (2013) and Gruber and Kamin (2007)). Some empirical papers turned their focuses to the imbalances in advanced economies (Decressin and Stavrev (2009) and Barnes et al. (2010)). The empirical section of my paper is inspired by this literature. It is worthwhile for the aim of this paper to mention that most of these studies find evidence for the twin deficit hypothesis (see for example Chinn et al. (2014), Bluedorn and Leigh (2011), Chinn and Ito (2007) and Chinn and Ito (2008)).

Very recent literature find empirical evidence that inequality is negatively associated with current account balance in industrial economies. In an innovative contribution Kumhof et al. (2012) argue that in advanced economies with developed financial markets, rising inequality leads to a deterioration of current account balances as the poor and middle classes borrow from the rich and from foreign lenders to finance their consumption. Marzinotto (2016) also finds that establishment of Euro area improved the external balance of more equal countries, whilst it deteriorates that in more unequal economies.

Belabed et al. (2013) by accounting for both personal and functional income distribution, argue that with upward-looking status comparisons, an increase in personal income inequality gives rise to "expenditure cascades" and deteriorates aggregate saving rate (see also Frank and Levine (2007) and Frank et al. (2010)). On the other hand, an increase in functional inequality, i,e, a fall in the households income share and an increase in the corporate income share, encourages the aggregate saving (since the capitalists/firms have higher propensity to save compared to the households) and improves the current account. Behringer et al. (2013) test these hypotheses empirically and find that rising top household income share significantly deteriorates the current account. They found also tentative evidence that current account increases as a result of a decline in the share of wages in value added. The results on the functional income distribution are also related to my paper since aggregate wage level can be influenced by wage centralization. The relation between households income share and current account can be different if the financial markets are integrated. In that case, low aggregate wage can attract external capitals due to higher return to investment. In the next section the relationships between wage centralization, households income share and current account will be discussed more precisely.

Literature on Wage centralization

The macroeconomic impact of wage centralization has been studied by a large number of articles. Calmfors and Driffill (1988) show that there is a hump-shaped relationship between the aggregate level of wage and the degree of wage centralization.[4] Even though the impact of wage centralization on wage level can play role in the determination of private savings and that of current account balances, a more important role of wage centralization, for the aim of this paper, is its impact on

[4]Therefore they conclude that countries with high level of wage centralization and the countries with very decentralized wage bargaining system have better economic performance and less unemployment rate compared with their counterparts with medium level of wage centralization, i.e. the countries where the wage is set in industry level.

inter-sectoral wage gaps and on the responsiveness of sectoral wages with respect to sectoral prices. Rycx (2002); Kahn (1998); Blau and Kahn (1999); Edin and Zetterberg (1992) show that, after controlling for workers skills and job conditions, the inter-sectoral wage gaps tends to be lower in countries with more centralized wage bargaining systems. Holmlund and Zetterberg (1991), Hartog et al. (2002) and Teulings and Hartog (1998) having the same result, concludes that industry wages in more decentralized countries are more sensitive to sectoral prices and productivity changes. By contrast, industry wages in more centralized economies (Nordic countries for example) are largely unaffected by the sectoral conditions.

Literature on Dutch disease

The theoretical model of this paper is, in its some features, inspired by the theoretical studies on the Dutch disease impact of natural resource and foreign aid. This literature consider a small open economy with two sectors: (i) tradeble sector and (ii) non-tradeable sector. This theoretical framework allows to capture the two symptoms of the Dutch disease raised by a shock in windfall income: (i) reallocation of resource from the T-sector to N-sector and (ii) appreciation of real exchange rate. The main references in this strand of literature are: Corden and Neary (1982), Torvik (2001) and Matsuyama (1992). The theoretical model of this paper differs from those mentioned above by considering the search and match friction in the labor market. This friction implies a short-term sectoral-wage dispersion as a result of a shock in windfall income.[5]

[5] To the best of my knowledge this paper is the first attempt in combining Dutch disease and Search & Match frameworks, even though the wage distributional impact of windfall income has important implications on the political economy of natural resource abundance.

Literature on search & match frictional labor market
The theoretical model incorporates search and match frictional labor market to account for short term impact of a shock in the twin deficits on sectoral wages. The search & match feature of the model extends Mortensen and Pissarides (1994), Mortensen and Pissarides (1999b) and Mortensen and Pissarides (2001) by allowing for two-sector economy. The search & match friction is studied by previous literature such as Hosios (1990), Davidson et al. (1987) and Davidson et al. (1988). The theoretical model differs from this literature by introducing wage centralization which is aimed to reduce the responsiveness of sectoral wages to a shock in sectoral prices (shock in real exchange rate).

3.3 Historical facts

The main hypothesis of this paper is that wage centralization reduces the current account through its negative impact on fiscal deficit. In this section, I focus on some stylized facts which are related to this hypothesis. The mechanism which is explained by this paper incorporates the twin deficits hypothesis. Some empirical papers have found evidence that 1 percent decline in fiscal deficits (% GDP) reduces the current account by 0.1-0.3 percent of GDP.[6] Bluedorn and Leigh (2011) control for changes in fiscal policies that are motivated primarily by fiscal deficit reduction, and hence, are largely uncorrelated with other factors affecting current account. They find that 1 percent of GDP fiscal consolidation raises the current account-to-GDP ratio by about

[6]See for example Alesina et al. (1991), Lee et al. (2008), Bussière et al. (2010), Chinn and Ito (2008) and Chinn et al. (2014).

0.6 percent point. As a historical example, in Belgium, budget balance deficits started to decline from -16 (% GDP) in 1981 to a surplus of 0.2% in 2001. This leads to a continuous improvement of the external balance from -4 (% GDP) in 1981 to +4,5 (% GDP) in 2001. The experience of the US in the beginning of 2000's is a well-known historical example of the link between the two deficits. The US budget balance (% GDP) falls continuously from 0.26 in 1999 to -4.7 and -4.3 in 2003 and 2004. In the same period, the current account (% GDP) dropped from -3 in 1999 to -5,2 and -5,7 in 2004 and 2005.

A standard implication of expansionary fiscal policy and its associated deficit in current account is appreciation of real exchange rate. The impact of the twin deficits on real exchange rate has been studied by empirical papers (See for example Bluedorn and Leigh (2011)). Theoretically, the link between the twin deficits and real exchange rate can emerge from the Mundell-Fleming model with flexible exchange rates, from open-economy general equilibrium with non-Ricardian features, as discussed by Obstfeld et al. (1996) and from the Dutch disease hypothesis:[7] An increase in the budget deficit, when Ricardian effect fails to be complete, leads to inflow of capital from the rest of the world. The inflow of capital increases the aggregate demand and deteriorates the trade balance. While the surge in the demand for traded goods can be satisfied by higher import, the supply of non-traded goods, such as services and construction, is limited to domestic productions. Therefore, in short-term a rise in the twin deficits and its associated capital inflow increases the relative price of the N-sector (which represents real exchange rate).

[7] In the theoretical model of this paper, this mechanism is used to explain the impact of the twin deficits on real exchange rate.

An increase in the relative price of the N-sector results in a reallocation of production factors from the T-sector to the N-sector. On the other hand, sector-specific labor skills and friction in the labor market, translates the appreciation of real exchange rate to shifts in sector wages in favor of the N-sector. The US data confirms these links. Figure (3.1,b) represents the employment ratio between the N-sector (services and construction) and the T-sector (manufacturing sector). While, the general trend is an increase in the employment share of the N-sector, this increase was accelerated between 1999 and 2008 financial crisis. Figure (3.1,a) represents the ratio between the averaged wage unit costs of the N-sector and that of the T-sector with reference to the ratio in 2010 (i.e. the ratio in 2010 is normalized to unity). This figure shows that the general trend has been the increase in the ratio in favor of the N-sector unit wage cost.[8] However, the trend was accelerated between 1999 and 2007. Therefore, these two figures are consistent with the short-term impacts of the twin deficits on factors reallocation and on inter-sectoral wage dispersion which is implied by the variation in real exchange rate.

These facts show that, when the government deteriorates the current account by increasing its deficits, the households affiliated to the N-sector enjoy the boost in that sector, while the households in the T-sector lose from less competitiveness of their sector and from a decline in their wage (in terms of domestic price level).[9] The other feature, which is used in the mechanism explained by this paper, is politi-

[8]The increasing trends can be explained by productivity rise and also the upturn in capital insensitivity of the T-sector.

[9]Workers who have more sector-specific skills are more touched by the policy.

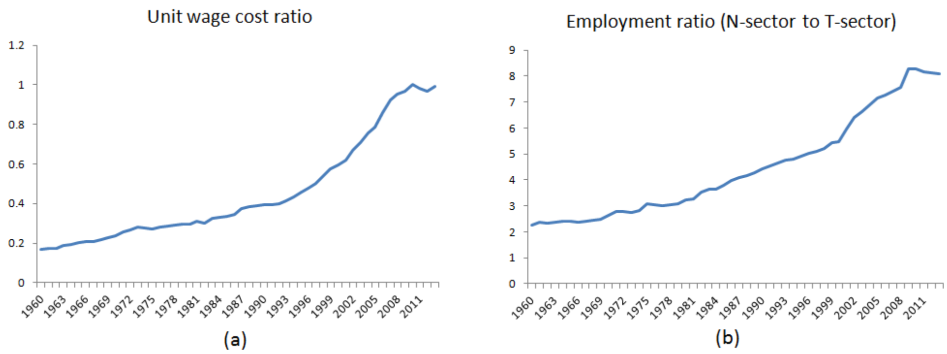


Figure 3.1: (a) US ratio between the average of unit wage cost in N-sector and T-sector with reference to 2010. (b) US employment ratio between N-sector and T-sector. (Source of data: AMECO)

cal economy framework. The government trying to keep its office, is more concerned with preferences of the majority. In all the industrial economies, a large and increasing majority of households are engaged in service and construction sectors. In the US for example, around 67% and 30% of employees were affiliated to the N-sector (construction and service) and T-sector (manufacturing), respectively, in 1960. These numbers changed to 88% and 11% in 2013. The same pattern can be found in other industrial economies. In 2013, the N-sector employment constitute about 88%, 90%, 82% and 78% of total employment in France, UK, Japan and Italy, respectively. Therefore, from a political economy point of view, one can expect that the government in industrial economies is mostly concerned with the impact of its policies on the N-sector workers and pay less attention to the consequences of its policies on the T-sector workers.

Wage centralization can play a role in this framework by moderating the impact of twin deficits policies, and hence that of changes in real exchange rate, on sectoral wages. It is known from the literature that wage centralization tends to reduce the responsiveness of sectoral wages with respect to sectoral prices. For example, Rycx (2002); Kahn (1998); Blau and Kahn (1999); Edin and Zetterberg (1992)) using cross-sectional analysis have shown that inter-sectoral wage gaps, after controlling for individual workers' skills and job conditions, tend to be lower in countries with more centralized wage bargaining system. Holmlund and Zetterberg (1991), Hartog et al. (2002) and Teulings and Hartog (1998) obtain the same result and conclude that industry wages in more decentralized-wage-system countries are more responsive to sectoral prices and productivity changes. In the framework of this paper, wage centralization moderates benefits and losses from twin deficits policies and the changes in real exchange rate. From this channel, wage centralization can influence the political incentives of governments in managing their fiscal balance through external debt/saving: governments in more centralized-wage countries find less political incentive for increasing their deficits through issuing foreign debts. They also face less political cost for improving their external debt position by reducing their fiscal deficits.

Hence, the prediction raised by this mechanism is that countries with more centralized wage bargaining system tend to have lower budget deficits compared to their counterparts with more decentralized wage bargaining system. This also implies more surplus in external balance for more centralized-wage economies if countries share the same characteristics in terms of other factors which may affect the current account. Figure (2,a) shows the relationship between non-overlapping 10-year averages of budget balance ($\%GDP$) and wage centralization between the period of 1980-2010 for countries reported in table 4. Wage centralization is measured by Iverson index. This index takes into account both level of wage setting and enforceability of bargaining agreements (Iversen (1998)).[10] The source of the data for the Iverson index is AIAS.[11] This index is ranged from 0, representing a system in which wage is completely decentralized and set at individual level, to 1, representing completely centralized wage bargaining system where all the wages are set by bargaining between unique national union and employer association.[12] This database provides yearly Iverson index for several industrial economies from 1960 to 2012. Table 4 in Appendix B reports the 10-year averages of the Iverson index for these countries during the last four decades. The rank orderings of countries according to different indices of wage centralization are reported in table 5. These rankings are induced by the indices suggested by the following papers: *(i)* Calmfors and Driffill (1988), *(ii)* Schmitter (1981), *(iii)* Cameron (1984), *(iv)* Blyth (1979) and *(v)* Bruno and Sachs (1985). As one can see in the table, the differences between the ranking induced by Iverson index and the other rankings in table 5 are minor.

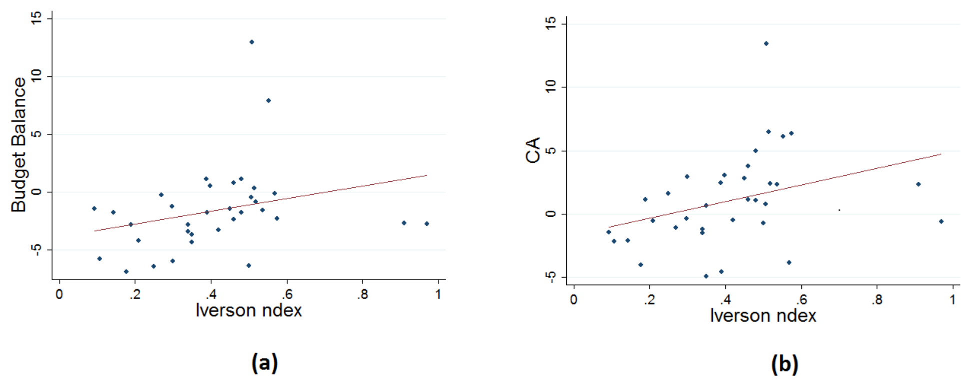
Figure (3.2,a) suggests a positive relationship between wage centralization and budget balance. Figure (3.2,b) shows the relationship between non-overlapping 10-year averages of current account ($\%GDP$) and wage centralization for the same countries and for the same period of time. This figure also suggests that higher centralization of wage

[10]These two dimensions are recognized by empirical papers as main variables affecting sectoral wage-to-price responsiveness (see for example Wallerstein (1999)).

[11]Amsterdam Institute for Advanced Labor Studies.

[12]In the sample of industrial economies used in this paper, the Iverson index is ranged between 0.1 (USA and UK) to 0.6 (Nordic countries) with the exception for Austria for which the Iverson index is above 0.9 in most of the years.

bargaining tends to go hand-in-hand with better external balance position in the cross section of industrial economies.



Wage centralization is measured by Iverson index. Each point in panels (a) and (b) represents, respectively, 10-year average of budget balance and current account for non-overlapping periods between 1970-2000.

Figure 3.2: **(a)** Budget balance (% GDP) vs. Iverson index, **(b)** Current account (% GDP) vs. Iverson index.

Up to here, I explained a mechanism through which wage centralization can have positive impact on the current account through the budget balance. However, some other channels can be identified through which wage centralization can have positive or negative effects on the current account. One of these channels is the impact of wage centralization on households savings through reducing inequality. The impact of personal inequality on private saving, and, hence on the current account, has been studied by recent literature (e.g. Kumhof et al. (2012) and Behringer et al. (2013)). Given inequality-households savings relationship, wage centralization can improve current account if it reduces personal income inequality. In Appendix B, I study this channel. The main findings confirm the results obtained by previous studies on wage centralization-inequality and on inequality-current account relationships. However, the findings demonstrate that wage centralization has no significant impact on households savings. The possible explanation can be that the positive impact of wage centralization on households savings through reducing inequality is offset by the negative impact of the former on the latter through increasing public saving (Ricardian effect).

The other possible channel through which wage centralization can affect current account can be through the impact of wage centralization on wage level. Low level of aggregate wages increases the international competitiveness of tradeable sector and can improve trade balance, and hence, the current account. Moreover, as Behringer et al. (2013) argue, a fall in the household income share (wage income) in value added (and, so, an increase in the corporate income share) increases the aggregate saving and improves the current account.[13] The impact of wage centralization on aggregate wage level was initiated by Calmfors and Driffill (1988). They found a hump shape relationship between wage level and the degree of wage centralization. More precisely, they showed countries with high level of wage centralization (with dominant bargaining at national/inter-sectoral level) and the countries with very decentralized wage bargaining system (bargaining at firm/individual level) tend to have lower aggregate wage compared to their counterparts with medium level of wage centralization, i.e. the countries where the wage is set at industry/sector level. Taking into account these two strands, one can expect that countries with medium level of wage centralization can moderate the wage income share if they pass to national level or to more decentralized wage bargaining system. Related to this mechanism, the so called German miracle has been put forward by some literature to support the idea that the de-

[13]Since firms/capitalists have more propensity to save.

centralization of wage bargaining can improve the external balance by restraining wage growth. This historical example is discussed in Appendix A. This historical example is worthwhile to be discussed since it is in contrast with empirical findings of this paper which support positive relationship between wage centralization and current account.

3.4 Econometric analysis

In the previous section, I document some stylized facts that support positive relationships between wage centralization and the two balances. However, there are a number of other candidate explanations for the two balances, some of them likely to be correlated with wage centralization. To account for this issue, I perform a multivariate analysis of current account and budget balance determinants using a panel of 16 OECD countries over the period 1980-2012. The sample of country are constrained by the availability of data on wage centralization index. The countries included in the econometric analysis are the ones reported in Table 4, excluding Austria which is an outlier in terms of the Iverson index.[14] In the first subsection, I test if wage centralization has explanatory power for current account. In this subsection I also test whether the twin deficits hypothesis holds for the sample. In subsection 3.4.2, I examine whether the effect of wage centralization on current account can be explained by its impact on budget balance.

[14]The Iverson index for all the countries in the sample are between 0.1 and 0.6. The Iverson index for Austria in different years varies from 0.9 to 0.96 which is much higher. Therefore, in the regressions, Austria is excluded from sample. Once Austria is included in the sample, the the coefficient of the Iversn index is not significant anymore. Nevertheless, once I account for the squared of the Iverson index the coefficient of the Iverson index becomes significant again, while the coefficient for the squared variable is negative and not always significant.

In subsection 3.4.3, I test the relationship between wage centralization and households savings, to test whether wage centralization can influence current account through households savings. Moreover, In Appendix B, I evaluate the relationship between wage centralization and inequality expressed alternatively as top 1% and 5% income shares and I test the hypothesis that wage centralization can affect current account through reducing inequality.

3.4.1 Current account and wage centralization

In this subsection, I test whether wage centralization has explanatory power for medium-term of current account positions. Besides, I test for the validity of the twin deficits hypothesis. This paper argues that wage centralization affects current account through the fiscal balance. To account for this issue, I implement the following strategy for different specifications and robustness checks: As a baseline model, I estimate current account (% GDP) using a benchmark set of explanatory variables which are used in the literature. This benchmark set includes budget balance and I test whether the twin deficits hypothesis holds in the sample. Key references in this literature include Chinn and Prasad (2003), Gruber and Kamin (2007), Chinn et al. (2014) and Kumhof et al. (2012) and the other papers which are reported in table 7. In the second step, I test whether wage centralization (represented by Iverson index) has significant explanatory power for current account once it is substituted for budget balance in the baseline model. Finally, I test a model in which both wage centralization and fiscal balance are included in the regression. Since, this model argues that the wage centralization can affect current account through budget deficit, one can expect that including the two variables in the regression at the same time must reduce the significance and magnitude of either or both variables. Therefore, three following specifications are considered for different measurements of the variables:

$$\frac{CA_{i,t}}{GDP_{i,t}} = \beta_0 + \beta_B \quad BudgetBalance_{i,t} + \beta X_{i,t} + \epsilon_{i,t} \tag{3.1}$$

$$\frac{CA_{i,t}}{GDP_{i,t}} = \beta_0 + \beta_C \quad WageCentralization_{i,t} + \beta X_{i,t} + \epsilon_{i,t} \tag{3.2}$$

$$\begin{aligned} \frac{CA_{i,t}}{GDP_{i,t}} = &\beta_0 + \beta_{BC} \quad BudgetBalance_{i,t} \\ &+ \beta_{CB} \quad WageCentralization_{i,t} + \beta X_{i,t} + \epsilon_{i,t} \end{aligned} \tag{3.3}$$

The dependent variable is the current account as a ratio to GDP in order to control for scale effects. $X_{i,t}$ is the benchmark set of explanatory variables that, in line with the existing literature, includes:

- **Initial net foreign assets**: Theoretically, the initial level of net foreign assets can have either a positive or negative effect on current account balance. On the one hand, initial net foreign assets can be used to finance trade deficits which may create a negative link between initial net foreign assets and the external balance. On the other hand, net foreign asset position affects positively the primary investment income from abroad, potentially leading to a positive relationship with the current account. Empirical studies have generally shown that the second channel is dominant. In fact, the NFA position is the accumulation of past current account surpluses. Hence, the lagged value of the NFA, expressed as a ratio to GDP, is used in the regressions to avoid capturing a reverse link from the current account balance to net foreign asset.

- **Relative income**: To capture stage of development effects, the variable relative per capita income is routinely included in current account regressions. I use the ratio of GDP per capita relative to the U.S. level. In anticipation of real convergence, private agents increase external borrowing to smooth their long-term consumption at an earlier stage of development. In addition, economic theory predicts that capital-rich developed countries export capital to more labor intensive countries where the productivity of capital is expected to be higher. From both channels, relative income is expected to have positive impact on the current account balance.

- **Financial development**: On the one hand, financial development has been viewed to encourage saving by reducing transaction costs and facilitating risk management. On the other hand, financial development can be interpreted as a proxy for the borrowing constraint faced by individuals in an economy, and can, therefore, be associated with higher levels of private borrowing. The impacts of financial development on domestic investment, which is the other side of current account, is expected to be positive. Even though, This paper do not have a strong prior on the relationship between financial deepening and the current account, I include this variable in our cross-country regressions. Private credit ration to GDP is used to measure the financial development.

- **Demographic variables**: The life-cycle hypothesis suggests that the saving behavior of households varies with age and is hump-shaped, reflecting higher levels of borrowing at younger phases, increased saving during the productive years, and a return to dissaving at the retirement age. I use old and young age dependency, as well as, population growth as proxy for demographic variables.

- **GDP growth**: Faster GDP growth makes the households to expect higher income levels relative to the present and, hence, households increase their consumption out of current income. Besides, higher growth resulting from productivity gains can attract foreign capital. For both reasons GDP growth is expected to have negative impact on the current account balance, although this result is not very robust across the related studies on industrial economies. To control for GDP growth, I use alternatively, changes in GDP-per-capita growth and GDP growth averages (the second one is used for robustness check).

The sources and descriptions of data used in the regressions are reported in table 6. The regressions do not include the country fixed effect (similar to Chinn and Prasad (2003), Gruber and Kamin (2007) and Chinn et al. (2014)), since including country-specific means prevents the model from analyzing cross country differences in current account and detracts from much of the economically meaningful parts of the analysis.[15] Moreover, for the most of the regressions, I use alternatively non-overlapping 3-year and 5-year averages of the data. This

[15] The main concern of this paper is wage centralization index. The time variation of this variable within the countries is small. Therefore, controlling for time-fixed-effects will prevent capturing the impact of this variable on dependent variables. In the regressions, I always control for Hausman test to be assured that using regressions with random effects do not have significant effect on the coefficient of the explanatory variables.

is due to the fact that the main interest of this paper is the medium term impact of wage centralization on current account. This procedure which is widely used in the literature (see for example Chinn and Prasad (2003), Gruber and Kamin (2007) and Cheung et al. (2013)) has also the advantage of abstracting from cyclical effects and other high frequency noises in the data. For robustness check, I reestimate the models with the annual data. The estimation with 5-year averages of data includes 6 period of time between 1982-2011 and for 3-year averages, 11 period between 1980-2012 will be considered.

Besides, I account for two different measurements of independent variables: (i) deviations from the GDP-weighted sample mean (with the exception for net foreign assets, relative income and Iverson index) and (ii) level data. The rationale for accounting for demeaning variable is to emphasize that current account balances are relative measures and their movements are influenced both by domestic and foreign economic conditions.[16]

The summary of results for baseline model (equation 3.1) are reported and compared with the literature in table 7 for the sample-demeaned data and for the level data (the results are associated to 5-year averages data). This table shows that our general results are consistent with the existing literature. The details results for this base-

[16]The rationale that the Iverson index is used as level rather than the deviation from sample mean is that its impact on current account is through the political incentives of the government for managing its budget. Therefore, its impact is independent from the centralization of wage in the rest of the world. For robustness check I account also for deviated measurement of Iverson index. The results are not sensitive to the choice of measurement of the Iverson index, even though in some regressions the coefficient of this variable becomes less significant with demeaned measurement.

line specification are reported in columns (1) and (4) (corresponding to 5-year averages and 3-year averages of data, respectively) of tables 3.1 and 8 (corresponding to sample-demeaned data and level data, respectively). The results confirm the twin deficits hypothesis in all the regressions. The impact of fiscal deficit on current account is relatively lower for regressions with the sample-demeaned data. Moreover, the coefficient less than one implies significant but not complete Ricardian effect. The impacts of population growth, initial net foreign assets and relative income are significant and consistent with the theory in all the regressions. Financial development and old-dependency ratio are not significant and they have opposite sign as what the theory suggests in the regressions with level data. But they become significant with consistent signs in the regressions with sample-mean deviation of the data. I found no significant impact of young-dependency ratio in level data regressions, but significant with opposite sign with theory in the regressions with sample-mean deviation of the data.

Wage centralization and current account

Since the purpose of this paper is to show the impact of wage centralization on current account and since the argument is that the mechanism goes through budget balance, I test a model where wage centralization is substituted for budget balance (equation (3.2)). The results for the two regressions by 5-year and 3-year averages of data and for level data and deviation data are reported in columns (2) and (5) of tables 8 and 3.1, respectively. The results suggest a significant and positive impact of wage centralization on current account: a higher level of wage centralization is associated with larger current account surpluses (or smaller current account deficits). Note that the Iverson index which is used as a proxy for wage centralization, varies from around 0.10 to 0.6

in my sample. Thus, for example, one can interpret the coefficient of the Iverson index in column (2) of table 3.1 as follows: ceteris paribus, changing the wage centralization from the most decentralized case to the most centralized case in our sample can lead to the improvement of current account by 3.6% of GDP.

In the next steps, I include both wage centralization index and fiscal balance in the regression (equation (3.3)). Columns (3) and (6) of tables 8 and 3.1 represent the results for regressions with 5-year and 3-year averages of data and for level data and for sample-demeaned data, respectively. The results show that including both Iverson index and fiscal balance at the same time, reduces coefficients and significances of either or both variables. For example, comparing the coefficients of the Iverson index in columns (5) with the one in column (6) in both tables 8 and 3.1 demonstrate that when the budget balance is not included in the model, the coefficient of the Iverson index is significant at 5 percent level, while when budget balance is included at the same time, the coefficient for wage centralization is not significant any more. These results can imply a correlation between the two variables. In the next subsection, I test if wage centralization has explanatory power for budget balance.

In order to examine the robustness of the results at higher frequencies, I reestimate the panel regressions for level data using the annual data rather than 5-year and 3-year averages. The results are reported in columns (1) and (2) of table 9. While the other variables seem to have the same effects as before, wage centralization seems to have no significant impact on current account in the annual regression. Since the data for wage centralization of Australia are mostly reported for every two or three years, there are many omitted observations which can influence our results, in annual regressions. Hence, in columns (3) and (4) of table 9, I exclude Australia from the sample. In this case, the coefficient for wage centralization is significant at 5 percent level again and the coefficient is close to the one in the regression with 3-year average data. The fact that the coefficient of wage centralization is more significant in 5-year averages specification than in the specifications with higher frequencies suggests that the impact of wage centralization on current account is mostly a medium impact.

Table 3.1: Panel Regression, OLS specification, Deviated from GDP-weighted sample mean

Current account	5-year averages			3-year averages		
	(1)	(2)	(3)	(4)	(5)	(6)
Govt. budget balance	0.256***		0.171*	0.310***		0.272***
	(0.089)		(0.097)	(0.070)		(0.077)
Iverson index		6.532**	6.111*		6.286***	3.691
		(3.007)	(3.186)		(2.105)	(2.465)
Private credit ratio	-0.022**	-0.024**	-0.018**	-0.016**	-0.013*	-0.013*
	(0.009)	(0.009)	(0.009)	(0.007)	(0.007)	(0.007)
Δ GDP growth	0.732	0.368	0.565	0.394	0.183	0.386
	(0.652)	(0.624)	(0.640)	(0.248)	(0.257)	(0.252)
Net foreign asset	0.054***	0.064***	0.063***	0.052***	0.059***	0.056***
	(0.009)	(0.010)	(0.010)	(0.007)	(0.007)	(0.008)
Relative income	4.650***	4.913***	3.851**	3.267***	4.336***	2.752**
	(1.601)	(1.643)	(1.644)	(1.241)	(1.254)	(1.321)
Population growth	-4.135***	-3.776***	-3.953***	-4.227***	-3.907***	-4.182***
	(0.953)	(0.963)	(0.949)	(0.722)	(0.736)	(0.739)
Trade openness	0.010	-0.010	-0.003	0.007	-0.004	0.002
	(0.010)	(0.012)	(0.012)	(0.008)	(0.009)	(0.009)
Old dependency ratio	-0.262**	-0.250**	-0.257**	-0.296***	-0.261**	-0.297***
	(0.121)	(0.127)	(0.121)	(0.097)	(0.102)	(0.104)
Young dependency ratio	0.108	0.208*	0.174	0.077	0.155*	0.106
	(0.113)	(0.118)	(0.116)	(0.090)	(0.089)	(0.093)
Constant	-4.052***	-5.874***	-5.017***	-2.730**	-5.253***	-3.355**
	(1.530)	(1.664)	(1.613)	(1.193)	(1.191)	(1.345)
Rsquared	0.67	0.65	0.69	0.62	0.58	0.63
Observations	89	91	89	156	158	153

Standard errors are reported in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

3.4.2 Government budget balance and wage centralization

In the previous subsection, I showed that wage centralization has significant and positive impact on the current account once it is substituted for budget balance in the baseline model of current account estimation. Moreover, I showed that the twin deficit hypothesis holds for the considered sample of industrial economies. In this subsection, I test if wage centralization has explanatory power for the budget balance when it is added to a set of explanatory variables of the public budget balance. Given the twin deficits hypothesis, if wage centralization reduces the public deficit, one explanation for the wage centralization-current account relationship would be through the impact of wage centralization on the budget balance.

To test this hypothesis, I estimate the budget balance by controlling for the Iverson index and a set of some candidate explanatory variables which are likely to affect the budget balance. The estimations have the following form:

$$\frac{BB_{i,t}}{GDP_{i,t}} = \zeta_0 + \zeta_C \quad WageCentralization_{i,t} + \zeta Z_{i,t} + \epsilon_{i,t} \tag{3.4}$$

The dependent variable is the budget balance as a ratio to GDP. $Z_{i,t}$ is the benchmark set of explanatory variables that include:

- Natural resource rent (%GDP) which is a windfall revenue for the government.
- Initial net foreign asset (%GDP) which can increase directly and indirectly the government revenue.
- Cyclical GDP per capita. This variable is measured as the devia-

tion of GDP per capita from its trend (using HP filter) as a ratio to the actual GDP per capita. In recessions, the fiscal deficit is likely to increase due to a decline in tax base and the possibility of expansionary fiscal policy.

- Old dependency ratio. Government is usually engaged with retirement payments. Therefore, old dependency ratio tends to increase fiscal deficits and at the same time reduce the tax base.
- Young dependency ratio. This variable tends to go to opposite direction with labor force and, hence, implies lower tax base. Moreover, the government is usually responsible for, at least, some parts of education fees for young people. From the two channels young dependency ratio tends to have negative impact on fiscal deficits.

All the data are measured as level. The sources and descriptions of data used in the regressions are reported in table 6. I estimate equation (3.4) using 5-year, 4-year, 3-year averages of data and also for annual data. The results are reported in table 3.2. The results confirm the positive and significant impact of wage centralization on budget balance. The impacts of GDP per capita deviation, natural resource rent and net feign assets are significant and consistent with theory. The impact of young dependency ratio is significant only for annual data. Our estimation does not identify any relation between old dependency ration and fiscal balance.

The main result from this subsection is that wage centralization has positive and significant impact on budget balance. Adding this to

Table 3.2: Panel Regression for Budget Balance

Dependent variable: Budget balance (%GDP)	5-year averages	4-year averages	3-year averages	Annual data
Iverson index	8.247***	8.968***	7.098***	6.526**
	(2.838)	(2.976)	(2.644)	(2.810)
Natural resource rent (%GDP)	0.602***	0.637***	0.640***	0.658***
	(0.118)	(0.120)	(0.104)	(0.083)
Net foreign asset (%GDP)	0.026***	0.032***	0.023***	0.022***
	(0.010)	(0.010)	(0.008)	(0.007)
GDP deviation	14.015	24.887***	11.819**	6.506***
	(12.053)	(9.539)	(5.268)	(2.273)
Dependency ratio (old)	0.042	0.018	-0.040	-0.110
	(0.115)	(0.113)	(0.098)	(0.077)
Dependency ratio (young)	0.104	0.001	-0.075	-0.201***
	(0.133)	(0.116)	(0.097)	(0.070)
Constant	-9.671*	-6.606	-2.646	2.591
	(5.615)	(5.281)	(4.495)	(3.471)
Rsquared	0.47	0.51	0.45	0.39
Observations	90	117	158	433

Standard errors are reported in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

the results for the validity of the twin deficit hypothesis in the previous subsection, implies that wage centralization can reduce the deficit in external balance by improving the budget balance position. Moreover, the results on the robust and positive impact of wage centralization on current account demonstrate that the impact of wage centralization on current account through the budget balance is not offset (at least completely) through other possible mechanisms. However, there is still the possibility that wage centralization improves current account through other channels as well. One other possible explanation for the positive relation between wage centralization and current account is the possible negative impact of wage centralization on inequality. [17] In appendix B, I reexamine the inequality-current account hypothesis introduced by Kumhof et al. (2012). Besides, I examine whether wage centralization can reduce inequality. The finding is that wage centralization can reduce current account by reducing inequality.

3.4.3 Wage centralization and households saving rate

Another interesting and related study is to test whether wage centralization has also impact on households' savings. According to existing theories and the findings of this paper, two opposite channels are expected. First, the positive impact of wage centralization on public saving can crowd out households' saving through Ricardian effect. Second, wage centralization can improve households savings through

[17] This possible explanation, if it holds, must be understood as a complementary rather than rival/alternative explanation for the mechanism of this paper, since the results from the previous and this subsections supports the hypothesis that there is a link between wage centralization and current account through the budget balance.

reducing personal income inequality, since inequality is expected to go hand to hand with lower households savings (Behringer et al. (2013)). To test the aggregate impact of wage centralization on households saving, I test the following specifications for 3-years and 5-year averages of data:

$$\begin{aligned} HSR_{i,t} = \alpha_0 + \alpha_I \quad & IncomeInequality_{i,t} \\ + \alpha_B \quad & BudgetBalance_{i,t} + \alpha X_{i,t} + \epsilon_{i,t} \end{aligned} \tag{3.5}$$

$$HSR_{i,t} = \alpha_0 + \alpha_C \quad wageCentralization_{i,t} + \alpha X_{i,t} + \epsilon_{i,t} \tag{3.6}$$

Estimation of equation (3.5) is inspired by Behringer et al. (2013). The dependent variable in both estimations is households saving rate. The data for this variable is taken from AMECO except for Canada and Australia for which the data is from OECD. $X_{i,t}$ is the same set of explanatory variables which is used for estimation of current account.[18] All the variables are expected to have the same sign as in current account regressions with the exception for budget balance that is expected to reduce private saving through the Ricardian effect. To test the impact of wage centralization on households private saving, I substitute this variable for budget balance and inequality. The results for 3-year and 5-year averages of data are reported in table 14 for demeaned measurements of the data. The estimations are performed with and without controlling for country-fixed-effects. The results suggest that both inequality and budget balance tend to reduce households private saving. However, wage centralization has no impact on household saving rate. This result can be explained by the the opposite impact of wage centralization on budget balance and inequality. Therefore,

[18]The rationale is that, in principle, this set of explanatory variables tend to affect the current account through households savings.

the positive impact of wage centralization on private saving through inequality and its negative impact through improving the budget balance partially offset each other.

To summarize, my empirical analyses suggest that wage centralization tends to improve current accounts in the cross-section of industrial economies. The results show that this impact is mostly through improving budget balance: wage centralization has positive and significant impact on public saving but no significant impact is identified on households saving rate. The empirical findings also confirms the negative impact of income inequality (expressed as top income share) on personal saving and, hence, on current account as suggested by Kumhof et al. (2012) and Behringer et al. (2013).[19] I also finds evidence that wage centralization tends to reduce inequality. Considering these two latter linkages together, wage centralization has two opposite impact on households savings: it can increase private saving by reducing inequality and it can reduces households savings by improving public saving (Ricardian effect). In the following section, I provide a theoretical model to explain the finding that wage centralization can improve the current account through its positive impact on public saving.

[19] No evidence is found for inequality-households saving and for inequality-current account relationships the data are measured with no-cross-sectional demeaning and when Denmark, Norway and Finland are added to the list of the countries that are used by these authors. Once these three countries are excluded from the sample, the results confirm these linkages even with level-data measurement. Nevertheless with cross-sectional demeaned data, the two linkages are always confirmed.

3.5 Theoretical model

3.5.1 Short description of the model

The model uses a political economy framework in which the policy maker follows preferences of N-sector workers which constitute the majority. It incorporates a small open economy with two sectors: T-sector and N-sector. The labor market is characterized by search and match friction. The government provides public goods financed through lumps-sum tax, external borrowing and return on foreign assets. The public good is built from a combination of the two goods. Private agents neither save nor borrow. Therefore, the budget deficit is equal to the current account and gives the magnitude of foreign capital inflows.

Running a budget deficit implies an increase in the amount of public good and a real exchange rate appreciation: an increase in the relative price of the N-sector good. As search frictions severely constrain between-sector labor mobility, the relative wage of workers in the N-sector goes up. Therefore workers in this sector support relatively more such twin-deficit policies since they enjoy higher provision of public goods and, at the same time, an increase in their wage. On the contrary, workers in the T-sector lose from their real wage due to the loss in international competitiveness of their sector.

The magnitude of these effects decreases with the degree of wage centralization. Unions promote wage equality. When wages are set at national level, wage inequality between sectors is reduced. More importantly, the sensitivity of sector-specific wages to changes in relative prices is lowered when the wage is more centralized. Thus, the gains and losses from twin-deficit policies are smaller.

To demonstrate this mechanism, the paper runs a numerical experiment. It assumes there is a positive shock on the current amount of foreign assets. The government spreads this additional resource over time so as to maximize the expected utility of a typical worker employed in the N-sector. The model shows that the policy maker is more patient in consuming the realized/expected increase in the valuation of its foreign assets if the wage bargaining is more centralized. Consequently, the model concludes that the magnitude of the current account deficit decreases with the degree of wage centralization.

3.5.2 Households

The households' utility depends on their private consumption (c_i) and public good provision (G) provided by the government:

$$u_i(c_i, G) = c_i + f(G) = c_i + z_1 G^{z_2} \tag{3.7}$$

I assume that the households are risk neutral with respect to their private consumption. This assumption rules out the possibility of private saving and simplifies the model. In fact, private saving is, indeed, an important component of current account and accordingly, this assumption must be justified. In subsection 3.7.1, I discuss the rational and validity of this assumption.

Following the literature on the Dutch disease, I assume that the basket of private consumption consists of final goods from the T-sector and the N-sector.

$$C_i(c_{i,T}, c_{i,N}) = c_{i,T}^{\gamma} c_{i,N}^{1-\gamma} \tag{3.8}$$

Given the sectoral prices, the household i decides about the optimal allocation of his consumption between the two sectors to minimize his cost for the given level of consumption:

$$\begin{gathered} \min P_N c_{i,N} + P_T c_{i,T} \\ \textbf{s.t. } c_{i,T}^{\gamma} c_{i,N}^{1-\gamma} = C_i \end{gathered}$$

Tradeable price is set as numeraire ($P_T = 1$). The household's static cost minimization problem leads to the following relation between his consumption share of each sector and the real exchange rate (relative price of the N-sector to the T-sector):

$$e = \frac{P_N}{P_T} = \frac{(1-\gamma)c_{i,T}}{\gamma c_{i,N}} \tag{3.9}$$

e in equation (3.9) represents real exchange rate. An increase in the relative price of one sector makes the household to substitute their consumption toward the other sector. Since the private consumption is homogeneous of degree one with respect to sectoral consumption, equation (3.9) leads to the following relation between the aggregate private demands for each sector and the real exchange rate:

$$e = \frac{P_N}{P_T} = \frac{(1-\gamma)C_T}{\gamma C_N} \tag{3.10}$$

3.5.3 Government

Government expenditure consists of constant unemployment benefit (b) and provision of public good (G_t). Government finances its expenditure by (i) lump-sum tax (τ_t) levied on employed households, (ii) gross return to its foreign assets and (iii) borrowing from international financial market. τ_t, G_t and b are in terms of the domestic price level.[20] Therefore, government budget constraint is of the following form:

$$G_t + bu_t = \tau_t \bar{n}_t + r\frac{A_{t-1}}{\bar{P}_t} + \frac{A_{t-1} - A_t}{\bar{P}_t} \tag{3.11}$$

A_t represents the net government foreign assets owned by the government. This variable is in terms of the T-sector price level which is internationally fixed. $\frac{A_{t-1}-A_t}{\bar{P}_t}$ is the government net borrowing or fiscal deficit and $\frac{rA_{t-1}}{\bar{P}_t}$ is the net return to foreign assets.

I define $B_t(= (1+r)A_{t-1} - A_t)$ as ***windfall expenditure***: the part of the government expenditure which is financed through borrowing or by the return to its foreign assets.[21] In other words, windfall expenditure is public budget deficit plus the net return to its assets. Using this definition, we can rewrite the public budget constraint in the following form:

$$G_t + bu_t = \tau_t \bar{n}_t + \frac{B_t}{\bar{P}_t} \tag{3.12}$$

Public good provision:

To produce public service/goods, government must buy tradable and non-tradable final goods from the market and costlessly combine them. For the sake of simplicity, I assume that the share of T-sector and N-sector goods are the same in public good provision as in the basket of

[20]Assuming lump-sum tax instead of linear or progressive taxes simplifies the model and, besides, rules out the distortionary impact of the other alternative tax forms.

[21]Notice that if $A_{t-1} > A_t$, the government finances partially its expenditure by borrowing.

private good (γ):[22]

$$G(g_T, g_N) = g_T^{\gamma} g_N^{1-\gamma}$$

The government minimizes its cost for a given level of public expenditure:

$$\begin{aligned} \min P_{N,t} g_{N,t} + P_{T,t} g_{T,t} \\ \textbf{s.t. } g_{T,t}^{\gamma} g_{N,t}^{1-\gamma} = G_t \end{aligned}$$

This minimization problem together with equation (3.9), lead to the following relationship between the sectoral aggregate demands and the real exchange rate:

$$e = \frac{P_N}{P_T} = \frac{(1-\gamma)(C_T + g_T)}{\gamma(C_N + g_N)} \tag{3.13}$$

We can also find the domestic price level in terms of the price of the T-sector (set as numeraire):

$$\bar{P} = \frac{1}{(1-\gamma)^{(1-\gamma)} \gamma^{\gamma}} P_N^{1-\gamma} \tag{3.14}$$

Equation (3.14) implies that appreciation of real exchange rate leads to an increase in the aggregate price level in terms of international price level (or equivalently a decline in T-sector price in terms of domestic price level).

[22]The impact of different intensities is discussed in discussion.

3.5.4 Market clearing

Market clearing implies that the total expenditure (private and public) equals the total revenue (production rent and the net return to the government's foreign assets) plus the national net borrowing $(A_{t-1} - A_t)$ which is the budget deficit.[23]

$$\begin{aligned} \bar{P}_t C_t + \bar{P}_t G_t &= Y_{T,t} + P_{N,t} Y_{N,t} + ((1+r)A_{t-1} - A_t) \\ &= Y_{T,t} + P_{N,t} Y_{N,t} + B_t \end{aligned} \tag{3.15}$$

By definition, the aggregate consumption of N-sector final goods is equal to the production in this sector:

$$(c_N + g_N) = Y_N \tag{3.16}$$

Equations (3.15) and (3.16) imply that windfall expenditure corresponds to trade deficit:

$$B_t = Y_{T,t} - (c_{T,t} + g_{T,t}) \tag{3.17}$$

Therefore, we can, equivalently, interpret B_t as current account deficit plus the net return to net foreign assets owned by the government.

Definition 1. *I define* **windfall expenditure** *as net borrowing plus the net return to foreign assets:* $B_t (= (1+r)A_{t-1} - A_t)$*. Since individual households do not have access to international financial market, we*

[23] This is due to the fact that in this model households do not save and, hence, they do not save/dissave in international financial market.

have:

$$\textit{Current Account deficit} = \textit{Budget deficit} \ = B_t - rA_{t-1} = A_{t-1} - A_t$$

Consequently, for a given deficit in trade balance, the higher is the government's initial net foreign asset, the lower would be the deficits in current account and in budget balance. Substituting equations (3.16) and (3.17) into equation (3.13), one can find the relative price of N-sector to T-sector (real exchange rate) as follows:

$$e_t = P_{N,t} = \frac{(1-\gamma)(Y_{T,t} + B_t)}{\gamma(Y_{N,t})} = \frac{(1-\gamma)(a_T n_{T,t} + B_t)}{\gamma a_N n_{N,t}} \tag{3.18}$$

This equation expresses an important symptom of the Dutch disease phenomenon: if production factors can not be immediately reallocated between the sectors, e.g. if there is friction in labor market, an increase in windfall expenditure leads to a real appreciation of currency. In other words, a positive shock in external borrowing, international interest rate (for the net creditors), or in the value of foreign asset brings about an appreciation of real exchange rate in short term. In the next subsection, I introduce the production side of the economy which is characterized by match friction in the labor market.

3.5.5 Production side and labor market

Production in each active firm depends linearly on labor. Each household is either unemployed or employed in one of the two sectors. If unemployed, he searches for a job in both sectors and he receives a constant and exogenous unemployment benefit *(b)*. If employed, he earns the real wage of w_j which depends on his sectoral affiliation *(j)*. When vacant, the firms in each sector search for workers with real cost *(c)*. When the job is active and matched with a worker, the firms produce final goods and enjoy the profit. Search is segmented: firms who search for jobs in one sector do not create congestion effect for the searching firms in the other sector.The matching process in each sector is governed by Cobb-Douglas function and depends on the unemployment rate *(u)* and the number of vacancies in that sector *(ν_j)*:

$$M_j = \phi \nu_j^{1-\alpha} u^{\alpha} \qquad \text{for } j \in \{T, N\} \tag{3.19}$$

where ϕ is the efficiency of matching function. Equation (3.19) gives the number of matches in each sector and in each unit of time. Therefore, the probability that a vacant firm in sector j meets a worker, (p_j^f), and the probability that an unemployed household meets a vacancy in sector j, (p_j^w) are respectively:

$$p_j^f = \phi(\frac{u}{\nu_j})^{\alpha} \quad , \quad p_j^w = \phi(\frac{\nu_j}{u})^{1-\alpha} \qquad \text{for } j \in \{T, N\} \tag{3.20}$$

Since households can search for jobs in both sectors, there is the possibility of $p_T^w p_N^w$ that a worker finds a job in both sectors. In this case with probability of 0.5 he will be employed in one of the two sectors. Therefore, the probability that a vacant firm in sector j matches with a worker, (q_j), and the probability that an unemployed household can find a job in sector j, (ρ_j), can be found by the following equations:

$$q_j = p_j^f - 0,5 p_{-j}^w \quad , \quad \rho_j = p_j^w - 0,5 p_j^w p_{-j}^w \qquad \text{for } j \in \{T, N\} \tag{3.21}$$

Moreover, in each period of time, an active job can be destroyed with the exogenous probability of χ. Therefore, the evolution of employment in each sector can be written by the following equations:

$$n_j' = \rho_j u + (1-\chi)n_j \quad \text{for } j \in \{T, N\} \tag{3.22}$$

In equation (3.22), n_j represents the number of workers in sector j. To open a vacancy and search for workers, the firms must pay the real cost c. Therefore, the value function of opening a vacancy in sector j is:

$$V_j = -c + \beta(q_j J_j' + (1-q_j)V'j) \tag{3.23}$$

where $J_{o,j}'$ is the next period value function of the employer in sector j and β is the subjective discount rate of the households. The value function of active employers in sector j can be represented by the following equations:

$$J_j = \frac{a_j P_j}{\bar{P}} - \omega_{e,j} + \beta E\Big[(1-\chi)J_j' + \chi V_j'\Big] \tag{3.24}$$

In (3.24), a_j and ω_j are sector-specific technology level, which is assumed to be given and constant, and wage in terms of domestic price level. P_j and $\bar{P}$ represent the price of the final goods in sector j and the domestic price level, respectively. Accordingly, the value functions of the workers in sector j is:

$$W_j = \omega_{e,j} - \tau + \beta E\Big[(1-\chi)W_j' + \chi W_u'\Big] \tag{3.25}$$

where W_u' is the next period value function of unemployed households. This value function can be expressed by the following equation:

$$W_u = b + \beta E\Big[\rho_T W'_T + \rho_N W'_N + (1 - \rho_T - \rho_N) W'_u\Big] \tag{3.26}$$

Free entry condition implies that the value function of vacancy creation is zero:

$$V_j = 0 \Rightarrow J'_j = \frac{c}{\beta q_j} \tag{3.27}$$

Using free entry condition, we can write the evolution of vacancy (3.24) in the following form:

$$\frac{c}{\beta q_j} = \frac{a_j p'_j}{\bar{P}'} - \omega'_j + \frac{c(1-\chi)}{q'_j} \tag{3.28}$$

This equation demonstrates another symptom of the Dutch disease phenomenon: the resource effect. Expecting a positive shock in real exchange rate induces higher (lower) vacancy creation in the N-sector (T-sector). Consequently, the model implies that an increase in the windfall expenditure lead to a reallocation of resources from the T-sector to the N-sector.

Wage setting

As explained before, the main role of wage centralization in this model is reducing inter-sectoral wage gap and hence, reducing the flexibility of wages with respect to sector-prices.[24] [25] To capture this impact of wage centralization, I assume that there exist two wage bar-

[24]In discussion, implications of the impact of wage centralization on reducing the intra-sectoral wage gap is discussed.

[25]For the impact of wage centralization on reducing inter-sectoral wage gaps and reducing the responsiveness of sectoral wages to sectoral prices see: Rycx (2002); Kahn (1998); Blau and Kahn (1999); Edin and Zetterberg (1992)). Holmlund and Zetterberg (1991), Hartog et al. (2002) and Teulings and Hartog (1998)

gaining levels in the economy: (i) bargaining at central level which is the outcome of horizontal coordination between sector-level unions, and (ii) bargaining at firm level. The objective of the central-level bargaining is to set an egalitarian wage for all the workers ($\bar{\omega}$) independent from their sector affiliation. [26] At firm level, wage (W_j^d) is set by bargaining between individual employee and firm. The market wages are the outcome of vertical coordination between these to levels of bargaining. This vertical coordination is directed at passing down the results obtained at a central level ($\bar{\omega}$) to firm level (Moene et al. 1993). The ability of central organization to pass its bargaining result to firm level determines the level of wage centralization. More formally:

$$\omega_j = (1 - \sigma^C)\omega_j^d + \sigma^C \bar{\omega} \quad j \in \{T, N\} \tag{3.29}$$

where σ^C, defined between zero and unity, represents the level of wage centralization. If the central organizations have perfectly dominant positions ($\sigma^C = 1$) and can perfectly enforce their egalitarian objective the wage would be $\bar{\omega}$ for all the workers. On the contrary if wage bargaining is completely decentralized ($\sigma^C = 1$), the wage (ω_j^d) would be the outcome of firm-level. This wage setting structure is similar to Boeri and Burda (2009),[27] which argues that the wage rate for a worker depends, on the one hand, on the productivity of his job (here, his sectoral productivity) and, on the other hand, on some egalitarian criteria which is enforced by the union.

[26]The motivation of the union to compress the wage dispersion can be based on its egalitarian criteria or its objective for insuring the workers against the volatility in sectoral prices and productivity.

[27]This paper is the most similar to our model in terms of definition and model of wage centralization.

I assume that wage centralization does not affect the aggregate share of workers from the total economic rent. In other words, central organizations attempt to reduce the inter-sectoral wage dispersion only by transferring some rents from high-paid to low-paid workers.[28] More formally:

$$\sum_j n_j \omega_j = \sum_j n_j \omega_j^d \tag{3.30}$$

Following Mortensen and Pissarides (1999a), Mortensen and Pissarides (1999b), Mortensen and Pissarides (1999c) and Pissarides (2000), decentralized wages (ω_j^d) is determined according to Nash bargaining between individual employer and worker. We assume the bargaining power of individual workers to be η. Therefore:

$$W_j^d - W_u = \frac{\eta}{1-\eta} J_j^d \quad j \in \{T, N\} \tag{3.31}$$

This leads us to the determination of hypothetical decentralized wage which is standard in the literature:

$$\omega_j^d = \eta \frac{a_j P_j}{\bar{P}} + (1-\eta)(\tau + b) + \eta \beta E\Big[\rho_T (W_T' - W_u') + \rho_N (W_N' - W_u')\Big] \\ \text{for:} \quad j \in \{T, N\}. \tag{3.32}$$

Equation (3.32) demonstrates that the decentralized wage in each sector is an increasing function of the price in that sector. Moreover, this equation implies that, the only source of wage disparity in the model is sectoral prices (and sectoral technology level which is consid-

[28] The impact of wage centralization on current account through its impact on wage level can be an interesting subject for future studies. This channel is briefly discussed in section 3.3.

ered to be exogenous and constant). Recall that the aggregate price level $\bar{P}$ is an increasing function of real exchange rate (P_N) and P_T is set as numeraire. Therefore, a positive shock in N-sector price level induces an increase (a decline) in hypothetical decentralized wage of N-sector (T-sector) workers. Using equations (3.29) (3.32) and (3.30), one can show the market wage in the following form:

$$\omega_j = \omega_{e,j}^d - \eta\sigma^C \frac{n_{-j}}{n_j + n_{-j}} (\frac{a_j P_j}{\bar{P}} - \frac{a_{-j} P_{-j}}{\bar{P}}) \qquad j \in \{T, N\} \tag{3.33}$$

This equation demonstrates that if wage is completely decentralized ($\sigma^C = 0$), workers earn their corresponding decentralized wage and if the wage is perfectly centralized ($\sigma^C = 1$), workers, independent from their job affiliation earn the average wage of the economy. Finally, equation (3.33) implies that the higher is the degree of wage centralization, the lower is the responsiveness of wage with respect to the corresponding sector productivity.

3.5.6 General equilibrium

Now we can define the dynamic general equilibrium of the model. For a given time profile of windfall expenditure B_t, the dynamic general equilibrium can be defined such that:

- Households consume all their revenue from net wage (if employed) and unemployment benefit (if unemployed).
- Given relative prices, households and government allocate their expenditure between T-sector and N-sector.
- Free entry condition holds (equation (3.28)).

- Wages depend on the bargaining between employers and workers and also the level of wage bargaining (equations (3.33)).
- Government budget constraint holds (equation (3.12)).
- Market clears (equation (3.18)).
- Employment in each sector depends on matching function, the characteristics of the labor market and sectoral wages and prices (equations (3.22), (3.19), (3.21)).

Accordingly, the following set of equations determines the dynamic general equilibrium of the model for a given time profile of windfall expenditure $\{B_t\}$: For $j \in \{T, N\}$, this system leads to 12 equations with 12 unknowns: $\{q_T, q_N, \rho_T, \rho_N, \nu_T, \nu_N, \omega_T, \omega_N, P_N,\ n_T, n_N, n_, \tau\}$.

3.6 Numerical analysis

In order to illustrate the mechanism explained in the previous section, in this section, I perform a numerical example. First, I calibrate the model (subsection 3.6.1). Then, in subsection 3.6.2, I examine the macroeconomic effects of a shock in windfall expenditure. In subsection 3.6.3, I show how workers in different sectors have different policy preferences when a shock in public foreign assets is realized.

3.6.1 Model calibration

In this subsection, I introduce the calibration of the model for a numerical example which illustrates the mechanism of the model. It is worthwhile to mention that the only variables which are qualitatively sensitive to the calibration are unemployment and tax. However, these variables are not the main concerns of this paper and, moreover, the impact of the shock on these variables are in second order with respect to the variables of our interest.

Matching and the labor market

den Haan et al. (2000) set the steady state separation rate (χ) equal to 0,1. This calibration is based on Hall et al. (1995) conclusion that around 8 to 10 percent of workers separate from their jobs each quarter. Merz (1995) and Andolfatto (1996) find the quarter separation rate equal to 0.7 and 0.15 respectively. I set the *monthly* separation rate equal to 0,03 to correspond approximately to the average of these studies. Following den Haan et al. (2000) and others, the bargaining power of workers is set to 0,5. Unemployment benefit (b) is set to be 13% of the steady state wage rate in the N-sector. The cost of opening a vacancy (c) is set to be equal to steady state minimum wage. To obtain the average unemployment rate of OECD country in 2014 (0.08), the level parameter of matching function (ϕ) is set to 0,077.

Utility function

To neutralize the effect of initial level of windfall income, I assume that the utility of households is linear in public good ($z_2 = 1$). Yet, any choice of $0 < z_2 < 1$ will not affect the qualitative results of this paper. Linearity of utility function with respect to its two components assures us that the steady state value of public expenditure has no impact on the results. I set steady state value of windfall income equal to around the average of the US trade deficit (ratio to GDP) in the last 5 years before 2000. This value is 1.2% of steady state GDP. I assume that the government maximizes the utility of households when deciding about its expenditure. Therefore, marginal utility of private consumption and public good are the same. Therefore, $z_1 = 1$. In the following section, I discuss the impact of different levels of z_1 on the households value function. To capture the fact that the majority of workers are engaged to the N-sector, I assume the consumption share of the T-sector (γ) to be 0.3. The monthly discount rate is set as 0.9947. Monthly interest rate is set equal to 0,042 % which correspond to annual interest rate of 0.5 %.

Production function

I normalize the T-sectoral technology level to unity ($a_T = 1$). Data from OECD finds that the averaged productivity ratio between industry sector and service sector is around 1,3. Accordingly I assume ($a_N = 1.3$). The calibrated parameters are reported in table 3.3.

3.6.2 Effect of shock in the windfall expenditure

Macroeconomic impacts of shock in windfall expenditure.

A positive shock in the windfall expenditure (B_t) leads to an increases in the the public demand and, thus, in the aggregate demand for final goods in both sectors (equation (3.15)). More demand in the T-sector increases the import from the rest of the world and so it leads to deterioration of trade deficit (equation (3.17)). However, by definition, the supply of the N-sector final goods cannot increase immediately (equation (3.16)). Consequently, the positive shock in the windfall expenditure leads to an appreciation in the real exchange rate: an increase in the relative prices of the N-sector to the T-sector (equation

Table 3.3: Calibrated parameters

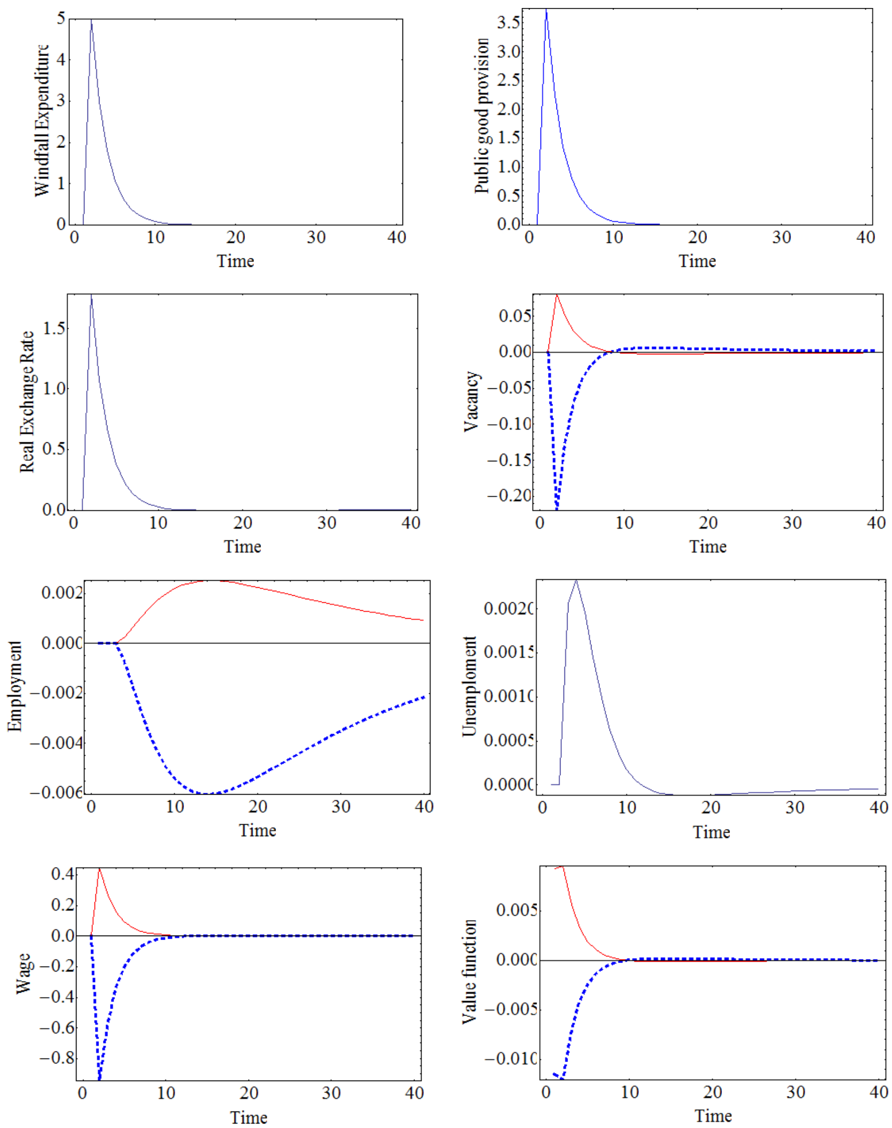
Symbol	Value	Interpretation
χ	0,03	Exogenous separation
α	0,5	Curvature parameter of matching function
c	0,25	Cost of vacancy
b	0,03	Unemployment benefit
ϕ	0,077	Level parameter of matching function
η	0,5	Workers' bargaining power
γ	0,2	Consumption Share of the T-sector
β	0,9947	Monthly discount rate
r	0,16 %	Monthly interest rate
z_1	0,1	Weight of public good in utility
z_2	1	Concavity of utility with respect to public good
a_T	1.3	Technology level in the T-sector
a_N	1	Technology level in the N-sector
B_{ss}	0.05	Steady state Windfall expenditure

(3.18)).

Real appreciation of currency increases (decreases) the economic surplus of matches in the N-sector (T-sector). Consequently, more vacancy will be created in the N-sector (T-sector) (equation (3.28)). Correspondingly, employment increases in the N-sector and decreases in the T-sector. During the transition period, N-sector workers, while enjoying a higher provision of public good, benefit from a higher wage. T-sectors workers, however benefit from a higher provision of public good only with the cost of decline in their wage and, thus, in their private consumption (equation (3.32)).[29] These results are depicted in figure 3.3. The impacts on sectoral employment rates and on sectoral wages are completely opposite if a negative shock in windfall expenditure is realized.

Effect of wage centralization.
As discussed before, a higher degree of wage centralization reduces wage dispersion between the two sectors by transferring some rents from the sector with higher wages to the sector with lower wages. Consequently, σ^C will decrease the sensitivity of sectoral wages with respect to variations of real exchange rate induced by the windfall shock. Figure 3.4 demonstrates sectoral wage responses to the same windfall shock. As it is clear from this figure, when $\sigma^C = 1$, windfall shock induces no inter-sectoral wage dispersion. Moreover, the wage rise for N-sector workers is smaller when the wage bargaining is more

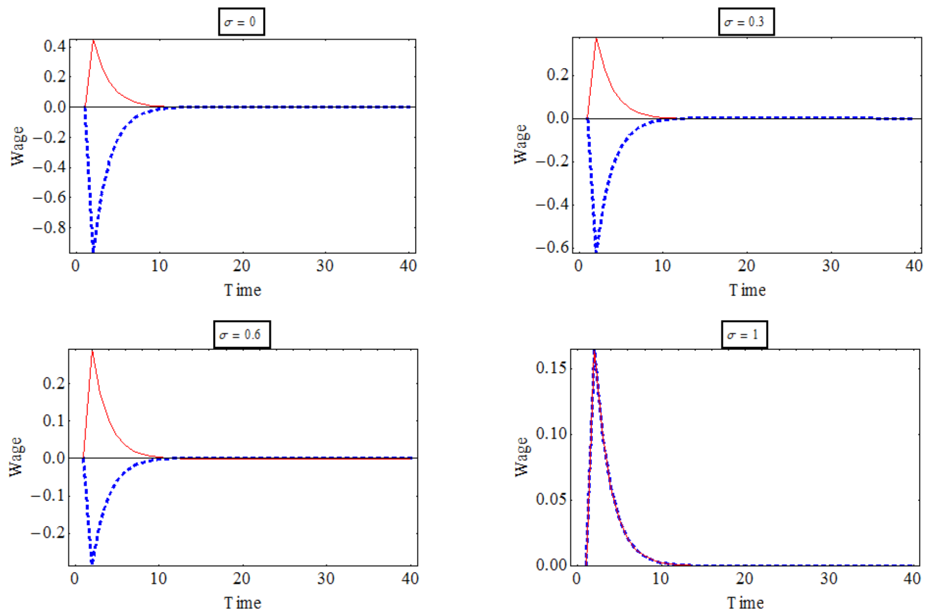
[29] The impact of the windfall income on unemployment rate, and so on tax rate, depends on the initial employment shares. Our calibration tries to capture the fact that N-sector workers represent the majority. Since matching function is marginally diminishing in number of vacancy, the windfall shock increases the unemployment. This result would be reversed if T-sector workers were the majority.



Solid line and dashed line correspond to N-sector and T-sector respectively.

Figure 3.3: Macroeconomic impacts of a positive shock in windfall expenditure.

centralized.



Solid line and dashed line correspond to N-sector and T-sector respectively.

Figure 3.4: Effect of wage centralization in reducing the responsiveness of sectoral wages.

Besides, higher centralization of wage bargaining increases the profit of the booming sector employers by reducing the wage responses. Consequently, wage centralization intensifies the increase (decline) in vacancy creation in the booming (disadvantageous) sector as a response to the windfall shock. Hence, the reallocation of labor to booming sector is accelerated by wage centralization. Faster reallocation of labors reduces the changes in the real exchange rate. These results are summarized in the following propositions.

Result 1. *If the labor market is frictional, a positive shock in windfall expenditure leads to:*

- *an increases (a decline) in the wage in N-sector (T-sector). Wage centralization mitigates these impacts.*

The impact of the shock on the households value functions Using equation (3.7) and relying on the assumption that the households do not save, we can write the inter-temporal utility of workers and that of the unemployed households as follows:

$$V_j = \Big(\omega_{e,j} - \tau + f(G)\Big) + \beta E\Big[(1-\chi)V_j' + \chi V_u'\Big] \tag{3.34}$$

$$V_u = \Big(b + f(G)\Big) + \beta E\Big[\rho_T V_T' + \rho_N V_N' + (1-\rho_T-\rho_N)V_u'\Big] \tag{3.35}$$

A shock in the windfall expenditure affects the workers' inter-temporal utility from two different channels: *(i)* the provision of public good (G) and *(ii)* the impact on real wages ω_j.[30] A positive shock in windfall expenditure affects positively the value function of the workers in the N-sector since they will enjoy an increase in wage (and hence, in private consumption) and, at the same time, a higher provision of public goods. Nevertheless, the impact on the value function of workers in the T-sector remains ambiguous since they enjoy a higher provision of public goods only with the cost of a decline in their wage. The fact that which effect dominates depends on the marginal rate of substitution between public good and private goods (z_1).

The higher is z_1, the more is the marginal utility of the public goods. Thus, the positive effect of windfall expenditure through the provision of public good dominates its negative impact through the

[30]The impact on the value function of the unemployed households is through public good provision and through the change in probability of finding job in the two sectors (ρ_T and ρ_N). The impact on the value function of the unemployed households is not the interest of this paper and I will not report it henceforth.

decline in wage (see figure C.1 in appendix). The opposite holds when the government reduces its windfall expenditure: Workers in N-sector will lose from lower wage and less provision of public goods, while the workers in the T-sector will enjoy more competitiveness of their sector. These results are embodied in the following proposition:

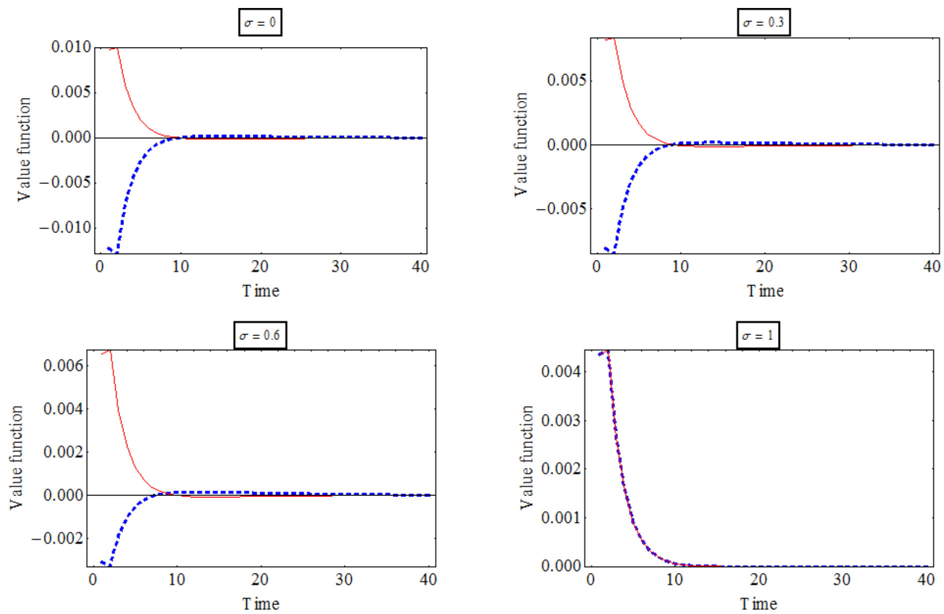
Result 2. *If the labor market is frictional,*

- *A positive shock in the windfall expenditure increases the welfare of the N-sector workers by providing them with higher public good provision and higher private consumption.*

- *The impact of the shock on the welfare of the T-sector workers is ambiguous since it provides them with higher public good only at the cost of less private consumption.*

This heterogeneous impacts on households' welfare is lessened with wage centralization since it reduces the sectoral wage gap raised by the shock in real exchange rate. Figure 3.5 depicts the impact of a shock in windfall expenditure on inter-temporal utility of households for the case of $z_1 = 0.1$ and for the different levels of wage centralization. This figure shows that centralization of wage reduces the gap between the inter-temporal utility of the households affiliated to different sectors. As a matter of fact, the higher is the σ^C, the lower is the welfare gain (loss) for workers in N-sector (T-sector).

These results suggest that N-sector workers relatively support more an expansion in the twin deficits. Their supports for such policies reduces with wage centralization.



Solid line and dashed line correspond to N-sector and T-sector respectively.

Figure 3.5: Effect of windfall expenditure on the household inter-temporal utility for the different levels of wage centralization.

3.6.3 Policy determination and the twin balances

In this subsection, first, I define the policy; then, I discuss the impact of the policy on households inter-temporal utility. I also evaluate the preferred policy of the households which will depend on their job status. Then, I discuss the effect of wage centralization on households preferred policy. Finally, in subsection 3.6.3, I will explain the policy determination and the effect of wage centralization on endogenous policy determination.

Definition of the policy

At steady state, the windfall expenditure is equal to the net return to foreign assets. Thus, there is no deficit in the two balances at steady state:[31]

$$B_{ss} = rA_{ss} \tag{3.36}$$

If the government expects a positive shock in the future value of its foreign assets with current amount of $\hat{A}$, it can decide about the time profile of expending this expected shock ($\{B_t\}$) such that the current amount of windfall expenditure equals to the current amount of asset shock:

$$\sum_{t=0}[\frac{B_t}{(1+r)^t}] = \sum_{t=0}[\frac{rA_{ss}}{(1+r)^t}] + \hat{A} = (1+r)A_{ss} + \hat{A} \tag{3.37}$$

Therefore, the policy can be interpreted as the optimal time allocation of the windfall expenditure $\{B_t\}$ such that equation (3.37) is satisfied. This policy, as it will be clear in subsection 3.6.3, is chosen through a political economic framework. For the sake of simplicity, I assume that the windfall expenditure follows a Markov process with persistence ρ_B and magnitude $\epsilon_{B,0}$:

$$B_t = B_{ss} + \rho_B^t \epsilon_{B,0} \tag{3.38}$$

Substituting from equation (3.38) into equation (3.37), we have:

$$\sum_{t=0}[\frac{\rho_B^t \epsilon_{B,0}}{(1+r)^t}] = \hat{A} \Rightarrow \epsilon_{B,0} = \frac{1+r-\rho_B}{1+r}\hat{A} \tag{3.39}$$

Equation (3.39) which is resulted from the inter-temporal budget

[31]Notice that $A_{ss} > (<)0$ implies a deficit (surplus) in trade balance.

constraint of the government, implies that the policy is uni-dimensional. Once the government decides about the shock persistence of its windfall expenditure (ρ_B), its expenditure at time zero and, hence, in every period of time, will be determined accordingly. When a positive shock in the future value of government foreign assets is realized ($\hat{A} > 0$), the government can increase the provision of public good. In this case, the higher is ρ_B, the more patient is the government to increase its expenditure (i.e. the provision of the public goods). More smooth will be the provision of public goods (see figure C.2). Consequently, the two balances will be relatively more balanced (more surplus /less deficit). On the contrary, the lower is ρ_B as response to $\hat{A} > 0$, the more impatient is the government: It provides more public goods today and less later. The opposite holds if a negative shock in the expected value of foreign assets is realized. In that case, higher ρ_B implies more deficits and a lower ρ_B implies less deficits.

Fact 1. *If a shock in the value of the government's assets ($\hat{A}$) is realized, then:*

- *If $\hat{A} > 0$, higher ρ_B (more smoothing policy) improves the two balances.*
- *If $\hat{A} < 0$, higher ρ_B (more smoothing policy) deteriorates the two balances.*

Effect of smoothing/accelerating policy on the household's value function

To understand better the impact of smoothing policy, I first consider an economy with perfect labor market.

Case of frictionless labor market:

If there were no friction in the labor market, labor forces could have been immediately adjusted to the shock. Consequently, the windfall expenditure would have no effect on the wages or on the private consumption.[32] Therefore, the only consequence of the windfall expenditure would have been to provide the households with higher provision of public good. Moreover, this impact would have been symmetric across the households. Therefore, in that case, the preferred policy would have been the same for all the households: the policy that guarantees the highest present value of the public goods provision. Note that in the case of perfect labor market, domestic price level ($\bar{P}_t$) would have been independent from B_t. This implies that for the case of linear utility with respect to the public goods ($z_2 = 1$) the households, independent from their job status, will prefer pure smoothing policy ($\rho_B = 1$) if and only if $r > \frac{1-\beta}{\beta}$ and they will prefer pure accelerating policy ($\rho_B = 0$) if and only if $r < \frac{1-\beta}{\beta}$.

Case of frictional labor market

The impact of the windfall shock and, consequently, that of the smoothing policy on the households welfare is more complicated if the labor market is frictional. On the one hand, friction in the labor market implies that windfall shock leads to a real appreciation of currency which can be interpreted as a decline in the value of windfall revenue

[32]Neutrality of windfall expenditure with respect to the wage, in the case of the perfect labor market, is due to our assumption that the production is linear with respect to the labor factor. If a concave production function is considered, the wages, real exchange rate and the aggregate price level will increase with respect to the T-sector prices. But in any case, the windfall shock would create no gap between the sectoral wages.

in terms of domestic price level (since windfall expenditure is in terms of the T-sector price level). This effect implies that the policy that maximizes the current value of the public goods is always greater in the case of a frictional labor market than in the case of a frictionless labor market. For example, for the case of linear utility with respect to public good provision, the policy which would maximize the current value of public good, would not be anymore the binary of $\rho_B = 1$ or $\rho_B = 0$. More precisely, in this case, even if the international interest rate is less than $\frac{1-\beta}{\beta}$, there would exist $\rho_B > 0$ which would maximize the current value of public good provision. The next proposition clarifies this result:

Result 3. *If the labor market is frictional, then there exist $r_{min} < r_{max} < \frac{1-\beta}{\beta}$ such that:*

- *If $r > r_{max}$, $\hat{\rho}_B = 1$ maximize current value of public good provision.*
- *If $r_{min} < r < r_{max}$, there exist $0 < \hat{\rho}_B < 1$ which maximizes current value of public good provision.*
- *If $r < r_{min}$, $\hat{\rho}_B = 0$ maximizes current value of public good provision.*

Figure 3.6 depicted the change in the current value of public good provision (raised by the shock) as a function of smoothing policy (ρ_B) for ($z_2 = 1$) and prevailing annual international interest rate of 3% (monthly net return of 0.25%). Note that for the calibration of $\beta = 0,9947$ (annual discount rate of $\beta_y = 0,94$, $\rho_B = 0$ would have maximized the current value of the windfall expenditure if the labor market was frictionless. I define $\hat{\rho}_B$ as the policy which maximizes the current value of public good.

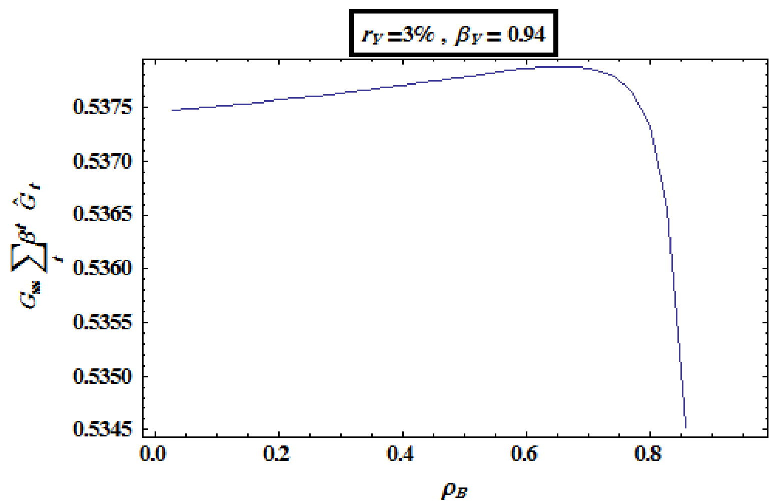


Figure 3.6: Effect of smoothing policy on the current value of public good provision.

On the other hand, as discussed in section (3.6.2), a positive shock in windfall expenditure raises the wage income for N-sector workers and reduces that for T-sector workers. Therefore, it is clear that the impact of the the policy is not symmetric across the workers if the labor market is frictional. If a positive shock in the government's foreign asset is realized, smoothing policy decreases the rise in the current value of expected wage for the workers in the N-sector and it mitigates the loss in the current value of expected wage for the workers in the T-sector. The reason is that, on the one hand, higher smoothing policy leads to less appreciation of real currency which implies less rise (decline) in the wage of the workers in the N-sector (T-sector). On the other hand, the higher is the ρ_B the more likely it is for the workers in the N-sector (T-sector) to exist from (to enter to) the booming sector.

The preferred policy by households depends on the impact of policy on both public goods and wage/private consumption. Since the impact on public good is heterogeneous, the workers in the N-sector prefer less smoothing policy than the workers in the T-sector. This result is just due to the heterogeneous impact of the policy on sectoral wages. More precisely, the preferred policy of the workers in the N-sector is smaller than $\hat{\rho}_B$ and that of the T-sector workers is larger than $\hat{\rho}_B$.

Result 4. *When a positive shock in the value of the government's foreign assets is realized, the workers in the N-sector support less smoothing policy than the workers in the T-sector. More precisely, if $\hat{\rho}_B$ represents the policy which maximizes the current value of public good provision, and $\rho_B^{\star,j}$ is the preferred policy of the workers in sector j, then:*

$$\rho_B^{\star,N} < \hat{\rho}_B < \rho^{\star,T} \tag{3.40}$$

The opposite holds if a negative shock is realized in the government's goreign assets.

Effect of centralization on households' preferred policy

The effect of smoothing policy on the discounted value of N-sector wages is monotonically negative as explained before. As discussed before, wage centralization reduces the response of wages to sectoral prices. Figure 3.7 represents the the effect of smoothing policy on the current value of changes in N-sector wages (as a ratio to steady-state value of wage) for different level of wage centralization. While the wage effect of the shock is always decreasing with the policy, its magnitude is lower when wage is more centralized. Nevertheless, wage centralization has no significant impact on $\hat{\rho}$. When wage is decentralized and the wage impact is high, the effect of policy on welfare is dominated by the effect of policy on wage. However, when wage is centralized, the impact on the provision of public good dominates the impact of policy on wage. Therefore, the preferred policy of N-sector workers converges to $\hat{\rho}$ when wage centralization is high and so the impact on wage is small. These results are depicted in figure 3.8. Figure 3.8 represents the impact of smoothing policy on the inter-temporal welfare of N-sector workers. When wage is completely decentralized, the effect of smoothing policy is similar to its policy on wage. However, when wage is very centralized the effect converges to the the impact of the policy on public goods, as the impact on wage is small. Therefore, N-sector worker in a centralized wage economy prefers higher ρ_B which implies less twin deficits.

On the contrary, in decentralized-wage economies, the impact of smoothing policy on T-sector wage rate is positive (see figure C.3). This implies that T-sector workers' preferred policy is higher than $\hat{\rho}$. Again the higher is the level of wage centralization, the lower is the impact of the shock on wages (see figure C.3). Hence, T-sector workers' preferred policy converges to $\hat{\rho}$ when wage is highly centralized. This implies that T-sector workers in more centralized economies prefer less smoothing policy compared to T-sector workers in decentralized-wage economies (see figure C.4). When $\sigma = 1$, both types of workers have the same evaluation for the policy.

Result 5. *The higher is the centralization of wage bargaining, the more (less) smoothing would be the preferred policy of the incumbent workers in the N-sector (T-sector) when a positive shock in the government's*

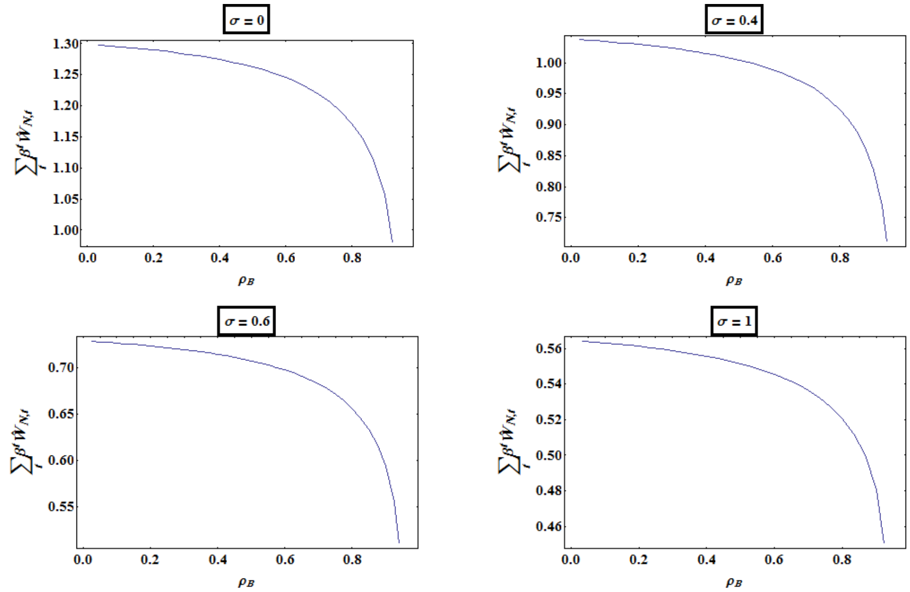


Figure 3.7: Discounted value of wage changes (% of steady state value) for N-sector workers as a function of smoothing policy for different levels of wage centralization.

assets is realized. The opposite holds if a negative shock is realized in the government's foreign asset. More formally:

$$\begin{array}{lll} \textit{if:}\hat{A} > 0: & \dfrac{\partial \rho_B^{\star,N}}{\partial \sigma^C} > 0 & \dfrac{\partial \rho_B^{\star,T}}{\partial \sigma^C} < 0 \\ \textit{if:}\hat{A} < 0: & \dfrac{\partial \rho_B^{\star,N}}{\partial \sigma^C} < 0 & \dfrac{\partial \rho_B^{\star,T}}{\partial \sigma^C} > 0 \end{array}$$

Policy determination and impact on current account

From political economic point of view, the policy is determined by majority of households. According to the data from developed coun-

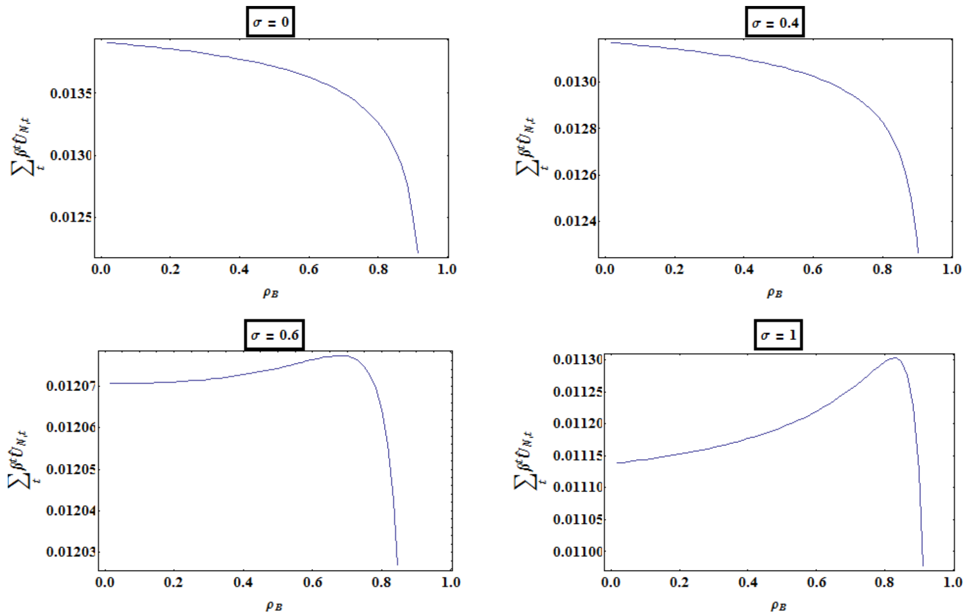


Figure 3.8: Inter-temporal utility of N-sector workers as a function of policy for different levels of wage centralization.

tries, majority of workers are affiliated to the N-sector. Therefore, the policy chosen by the government is likely to present the preferred policy of the workers in the N-sector.

According to result (5), centralization of wage bargaining pushes the preferred policy of the N-sector workers to be more smoothing. Consequently, this model suggests that in democratic countries where majority of households decide about the policy, the prevailing policy is more smoothing if the wage bargaining is more centralized.

3.7 Model discussion

3.7.1 Discussion on the assumptions for utility function

In the theoretical part of this paper, I rule out the possibility of private saving. This assumption considerably simplifies the model. Nevertheless, private saving is an important component of current account and, therefore this assumption must be justified. The focus of the theoretical part of the paper, is the impact of wage centralization on current account through public saving/expenditure. As long as Ricardian equivalence is not complete, the impact of public saving on current account is not perfectly offset by private dissaving and, therefore, our theoretical results on the impact of wage centralization on current account remain valid qualitatively. The empirical results on current account, including our results in the previous section, point out an incomplete Ricardian equivalence which can justify the qualitative results arisen from this assumption. Moreover, the empirical results of this paper demonstrate that wage centralization has no significant impact on private savings since wage centralization, from another channel, can encourage private saving by reducing personal income inequality. This empirical results can also assure us that assumption on non-Ricardian households will not affect the qualitative results of this paper.

Moreover, I assume additive separable utility function with respect to private and public goods. Relaxing this assumption, if public goods and private consumptions are complementary, an increase in G will increase private saving which intensifies current account deficit. In this case, even an increase in public good provision backed by tax will lead to deterioration of current account through reducing public saving (if households have access to international financial market). On the contrary, if G and C are substitutable, an increase in G motivates the households to save internationally. Hence, the impact of the budget deficit on current account will be moderated.

3.7.2 Intra-sectoral wage compression

In the theoretical part of this paper, I argued that wage centralization affects the political incentive of the government in managing its budget balance, and so the current account, by reducing the inter-sectoral wage dispersion. Here, I discuss that wage centralization can have similar impact on the two balances if it reduces intra-sectoral wage dispersions as long as they are arisen by job-specific or sector-specific human capital. Job-specific human capital can be accumulated by workers by job seniority (Topel (1990), Becker (2009)) and by the investment of employers on the job-specific skills of the workers (Acemoglu and Pischke (1998)).[33] Therefore, job seniority can increase wages for workers with more job seniority. On the other hand, wage centralization can reduce the wage gap between the workers with different individual human capital/efficiency (See for example Cahuc and Zylberberg (2004) and Wallerstein (1999)). Combining these two impacts together, one can deduce that wage centralization reduces the wage gap between the workers with different job seniority.

If a positive shock in the twin deficits is realized, workers will be re-

[33] Pissarides (1994) uses similar formulation to capture the impact of job seniority on the job-specific human capital.

allocated from the T-sector to the N-sector. The new matched workers in the N-sector have relatively less job-seniority and, hence, less sector-specific human capital. Consequently, the proportion of low-skilled to high-skilled workers will increase in the N-sector. If wage centralization reduces the gap between high skilled and low skilled workers by rent sharing between the two groups of workers, incumbent workers in the N-sector will realize relatively less wage rise compared to the case where wages are less centralized. This reduces their thirst for such twin deficits policy. Correspondingly, the government following preferences of workers in the N-sector will find less political incentive to increase its expenditure financed by foreign debt. This channel is in second order compared to the channel explained in the theoretical part of the paper since it effect is only through rent sharing of the incumbent workers with reallocated workers who are relatively small proportion of total employment.

3.7.3 Time inconsistency: from short-run to long-run

The numerical analysis of the paper obviously faces time-inconsistency problem since I implicitly assumed that the government commits to its announce policy on ρ. When a positive shock in public foreign assets is realized, in the periods after the announcement of its policy ρ, the government which follows preferences of N-sector workers, has incentive to choose a lower ρ to postpone saving and to provide more public expenditure compared to its prior announcement. Similarly, when a negative shock in the foreign assets is realized, the government has always incentive to deviate to a higher ρ to postpone its fiscal consolidation. This can give us an intuition for better understanding of long-term implications of the model. The government in more decentralized-wage countries, has more political incentive to deviate from its announced policy toward less fiscal consolidation and more fiscal expansion. The search&match feature of this model prevents from having a time-consistent analysis of the policy. One possible extension of this theoretical framework is to abstract from serach&match labor market and assume sector-specific labor skills which perfectly prevents inter-sector labor mobility. Such framework can facilitates the analysis of time-consistent policy determination.

3.8 Summary and conclusion

One new contribution of this paper is to introduce a relationship between wage centralization and current account imbalances. The empirical results of this paper demonstrate a positive and significant relation between wage centralization and current account in a cross-section of industrial economies. The findings identify two different and complementary explanations for the positive impact of wage centralization on current account. The first explanation relies on the twin deficit hypothesis and argues that wage centralization tend to improve current account by improving fiscal balance. The second explanation puts forward the hypothesis that wage centralization discourages private borrowing by reducing inequality. The twin deficits hypothesis, wage centralization-inequality relation and inequality-current account link are known from the existing literature. However, the relationship between wage centralization and fiscal balance is new. To explain this new empirical finding, this paper provides a theoretical model.

The theoretical model incorporates a political economy framework in which policy maker follows preferences of N-sector workers which constitute the majority. The government can increase public goods with borrowing from the international financial market. The public good is built from a combination of the two goods: tradeable and non-tradeable final goods. Running a budget deficit financed by foreign debt leads to the appreciation of real exchange rate appreciation: an increase in the relative price of the N-sector good. As search frictions severely constrain between-sector labor mobility, the relative wage of workers in the N-sector goes up. Therefore workers in this sector support relatively more such twin-deficit policies since they enjoy higher provision of public goods and, at the same time, an increase in their wage. The magnitude of these effects decreases with the degree of wage centralization: unions promote inter-sectoral wage equality and, consequently, the sensitivity of sector-specific wages to changes in relative prices is lowered when the wage is more centralized. Thus, the gains and losses from twin-deficit policies are smaller. This reduces the thirsts of the N-sector workers for higher twin-deficits and their dismay for a reform in the two balances. Therefore, the government observe less support for widening the two-deficits and less political cost for reforming the external balance through reducing its deficits.

One should be careful about policy implications of the results. Even though the paper suggests that wage centralization improves current account, one should notice the possibility of the negative impact of the former on growth and investment. The existing literature suggests decentralization of wage beginning as a policy which can lead to wage flexibility, higher growth and better market performance. This paper does not rule out these hypotheses. Nevertheless, this paper suggests that labor market can have important impact on the current account. This calls for homogenizing labor market arrangements inside the currency unions.

One restriction of the empirical study in this paper is the lack of data for wage centralization. Once more data is available, the validity of the hypotheses of this paper can be reexamined by w wider range of industrial countries. Theoretical framework provided by this model is also restricted by assuming no private saving. One future study can be a model which accounts for private saving with friction in international capital movement. Such a study can capture also an incomplete Ricardian effect which is absent in my model.

Appendix A: Wage centralization, wage level and current account: German Miracle

Decentralization of wage bargaining in Germany started from the mid 90's. In West Germany and East Germany the proportion of employees subject to area-wide wage agreement fell from, respectively, 72.2 and 56.3 percent in 1995 for West Germany and in 1996 for East Germany to 62.9 and 42.7 percent in 2002 (Ochel (2005)). The German current account, however, started to increase only after 2000, one year after the establishment of the Euro area (see figure (A.1,a)). Between 1995 and 2000, when wage decentralization had been already in process, the German external balance was still in its steady deficit trend of around 1.5 percent of GDP. Moreover, the wage share continued its steady trend of after the German reunification till 2003. The decline in wage share started only after 2003: the wage share in manufacturing declined from 70 percent to 63.5 and 62 percent in 2006 and 2007 (see figure (A.1,b)) .[34] The main and distinguishing labor market reform in 2003 was not decentralization of wage bargaining. Rather, the so-called Hartz labor market reforms in 2002 can better explain this decreasing trend in wage share in Germany. The Hartz committee focused on reducing unemployment duration by strengthening incentives to actively search for a job, and on improving job placement. Hartz labor market reforms shortened the period in which unemployment benefit is paid. It reduced the benefits for long-term unemployment. It tightened the conditions for unemployed households to refuse a job and finally, it abolished the early-retirement options. All these reforms

[34]Similar to several industrial countries wage share in manufacturing increased in 2008 and 2009 to 66 and 73 percent in 2008 and 2009 (in Germany) and declined afterward to almost steady trend around 65 percent.

lead to significant increase in labor market participation, to reduction in unemployment and, more related to this paper, to decline in wage level (see Jacobi and Kluve (2006) and Krebs and Scheffel (2013) for more details on the macroeconomic impacts of the Hartz labor market reforms). Therefore, it seems that it was mostly these later reforms that are responsible for the reduction in German aggregate wages and not the decentralization of wage bargaining.

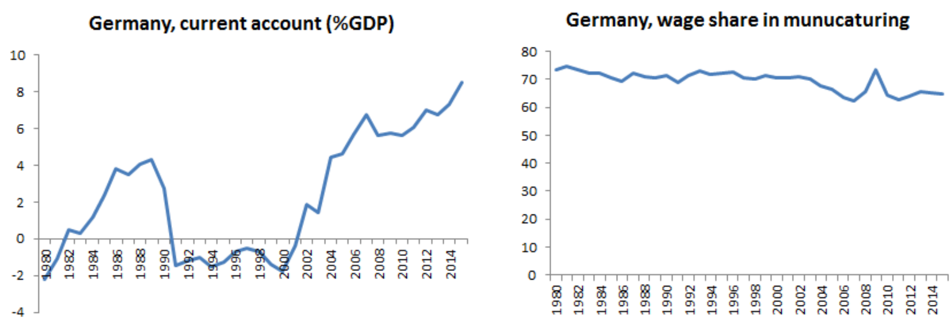


Figure A.1: **(a)** Current account (% GDP) (Data from IMF outlook, 2016) **(b)** Share of wage income in manufacturing sector (Data from AMECO).

Nevertheless, wage reduction and its associated increase in competitiveness was not the only source of the observed increase in the German current account which is realized after 2000. Kollmann et al. (2015) attributes the steady rise in the German external balance to other factors such as: (i) the establishment of the Euro area and its associated increase in financial integration in Europe which triggered capital flows from Germany to the rest of Europe. (ii) strong growth in emerging countries which boosted the demand for investment goods, given the German's specialization in those goods. (iii) the growth of outsourcing by German firms to low wage countries, notably in Eastern

Europe. (iv) high saving rate in Germany that can be due to the demographic changes in Germany. It is also worthwhile to mention that if the financial market is highly integrated, low wage share implies profitability of investment and inflow of foreign capital. Therefore, it is not theoretically clear if there is a negative relation between the aggregate wage level and the current account.

Appendix B: Wage centralization, inequality and current account

In this subsection, I test a possible complementary explanation for the positive impact of wage centralization on current account. This complementary explanation relies on wage centralization-income inequality linkage and on inequality-current account hypothesis: (i) wage centralization tends to reduce inequality. (ii) Inequality tends to affect negatively the current account (Kumhof et al. (2012), Behringer et al. (2013)). In the first step, I test the first hypothesis for my sample. In the second step, I test the impact of inequality on current account when it is added to the benchmark set of the explanatory variables of current account.

Inequality and wage centralization

To be consistent with Kumhof et al. (2012), I use alternatively the top 1% and 5% income shares as a proxy for income inequality. I estimate these two proxies separately as a function of some candidate variables from the benchmark explanatory variables of current account that are likely to have impact on income inequality. For both measures of inequalities, I test the two following specifications using 3-year averages and 5-year averages of the data:

$$Incomeinequality_{i,t} = \gamma_0 + \gamma X_{i,t} + \epsilon_{i,t}$$
$$Incomeinequality_{i,t} = \gamma_0 + \gamma_C \quad wagecentralization_{i,t} + \gamma X_{i,t} + \epsilon_{i,t}$$

The dependent variable is income inequality which is represented alternatively by top 1% and top 5% income shares. The source for the data on inequality is the same as in Kumhof et al. (2012) (The World Top Incomes Database). $X_{i,t}$ is a set of candidate explanatory variables which includes: private credit ratio to GDP which is a proxy for financial development, average GDP growth (time invariant variable), net foreign assets (% GDP), old and young dependency ratios. The sample of countries are the same as in subsection 3.4.1 excluding Belgium for which the data for inequality does not exist in TWTID. The data are measured with no cross-sectional demeaning.

The results for these regressions are reported in tables 10 and 11 for the top 5% and 1% income shares, respectively. In each table the regressions for 3-year and 5-year averages of data are reported for the specification without and with including the Iversson index. The results from table 10 suggest that wage centralization tends to substantially reduce top 5% income share in the panel of industrial economies. One must notice that including the Iverson index in the set of explanatory variables increases the R-squared to more than double. The impact of wage centralization on top 1% income share is rather tentative and smaller compared to the impact on top 5% income share. This can be explained by the fact that wage income, which is directly affected by wage centralization, constitutes relatively higher share of total income for households in top 5% income level than for households in top 1% income level. In other words, for the households in top 1% income level, a large share of total income is from capital income which is not directly affected by wage centralization. Since the main interest of this paper is wage centralization, henceforth, I focus more on the top 5% income share.

According to the results reported in table 10, financial development, average GDP growth, initial net foreign asset (% GDP) and to a lesser extent, old dependency ratio goes in the same direction with inequality, while, there is tentative evidence that relative income and young dependency ratio generally have negative impact on inequality. The positive impact of relative income on inequality is consistent with Kuznets curve.

Current account, inequality and wage centralization

To test the impact of inequality on current account, I test the following specifications for 3-years and 5-year averages of data:

$$\frac{CA_{i,t}}{GDP_{i,t}} = \alpha_0 + \alpha_I \quad IncomeInequality_{i,t} + \alpha_B \quad BudgetBalance_{i,t} + \alpha X_{i,t} + \epsilon_{i,t}$$

$$\frac{CA_{i,t}}{GDP_{i,t}} = \alpha_0 + \alpha_C \quad wageCentralization_{i,t} + \alpha X_{i,t} + \epsilon_{i,t}$$

Income Inequality is measured alternatively as top 5% and 1% income shares. $X_{i,t}$ is the same set of explanatory variables as in subsection 3.4.1. I test the models with demeaned data (except for the NFA, relative income and the Iverson index).[35] In table 12, I report

[35] Using cross-sectional demeaned measurement for these three variables is tested

the results of these regressions for 3-year and 5-year averages of the data. The results suggest that both the twin deficits hypothesis and inequality-current account hypothesis are significant.[36] Columns (3) and (6) also confirm again the positive impact of wage centralization on current account once this variable is substituted for inequality and budget balance.[37]

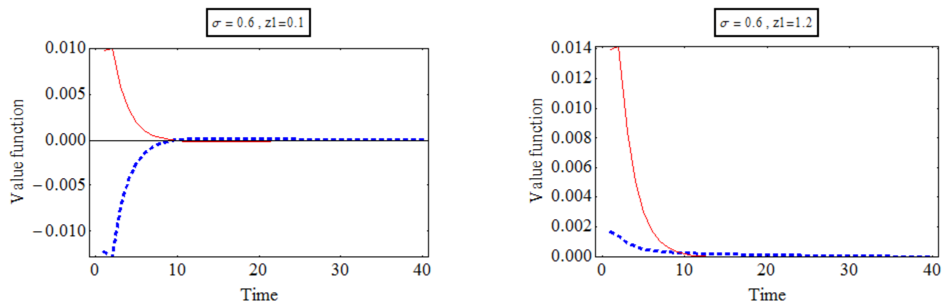
By using the same regressions with the level data, no evidence is found for inequality-current account hypothesis. Hausman test rules out the validity of random effect regression when both inequality and fiscal balance are included in the model. The same regressions with level data and by controlling for country-fixed effects again verifies the both hypothesis. The negative impact of inequality on current account and the negative impact of wage centralization on inequality suggest that, wage centralization can have positive impact on current account through reducing inequality.

(not reported). the results are not sensitive to the choice of measurement for these variables.

[36] This result is different from that of Kumhof et al. (2012) in the sense that they found that the more important role is played by top 1% income share, while the results of this paper identify a more significant impact of the top 5% income share.

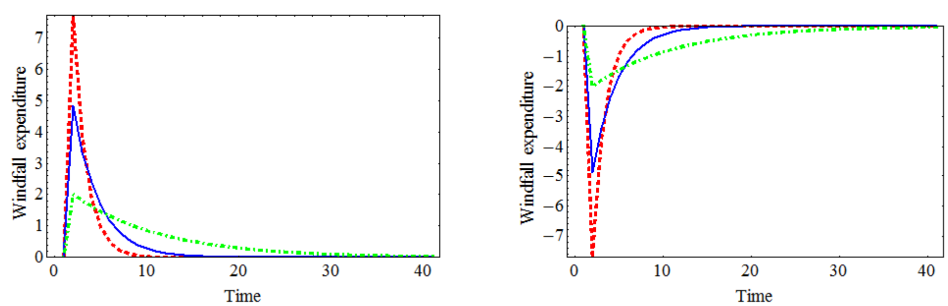
[37] Once the three variables are included in the model, Iverson index is not significant which implies the high correlation between wage centralization and the two other variables. In fact the correlation of the Iverson index with budget balance and the top 5% income share is 0.38 and -0.7.

Appendix C: Graphs



Solid line and dashed line correspond to N-sector and T-sector respectively.

Figure C.1: Effect of Windfall expenditure on the household intertemporal utility for different marginal rate of substitution between private and public goods.



Solid line (blue): Shock in windfall income. Dashed line (red): Windfall expenditure with accelerating policy. Dot-dashed line (green): Windfall expenditure with smoothing policy.

Figure C.2: Effect of smoothing policy.

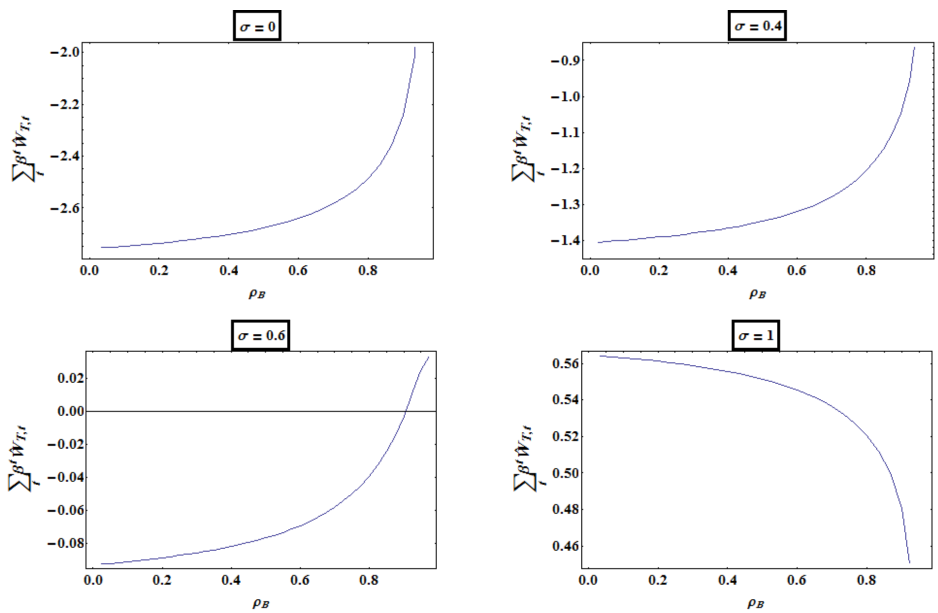


Figure C.3: Discounted value of wage changes (% of steady state value) for T-sector workers as a function of smoothing policy for different levels of wage centralization.

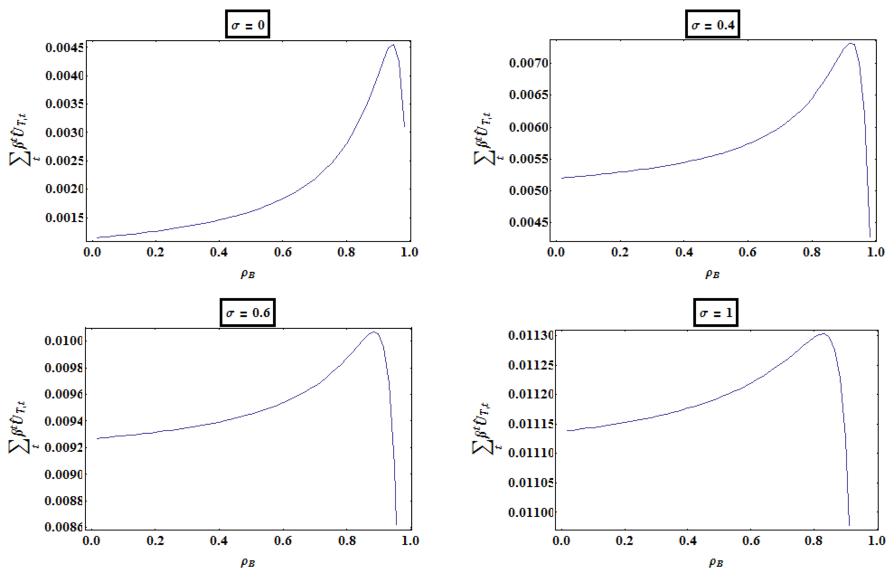


Figure C.4: Inter-temporal utility of T-sector workers as a function of policy for different levels of wage centralization.

Appendix D: Tables

Table 4: Iverson index (*)

Country	70's	80's	90's	2001-2012
US	0,12	0,12	0,14	0,18
UK	0,40	0,10	0,09	0,11
France	0,19	0,20	0,19	0,21
Japan	0,17	0,21	0,25	0,30
Canada	0,28	0,25	0,27	0,30
Spain	0,27	0,31	0,34	0,35
Italy	0,32	0,31	0,35	0,34
Switzerland	0,34	0,34	0,28	0,32
Finland	0,42	0,40	0,39	0,40
Australia	0,47	0,64	0,57	0,39
Belgium	0,47	0,45	0,45	0,46
Germany	0,46	0,41	0,42	0,48
Denmark	0,57	0,52	0,51	0,46
Sweden	0,56	0,53	0,52	0,51
Netherlands	0,48	0,54	0,54	0,57
Norway	0,61	0,56	0,55	0,51
Austria	0,95	0,97	0,97	0,91

(*) Sources for the Iverson indices: AIAS

Table 5: Rank ordering of countries according to their degree of wage centralization

Ranking	Calmfors-Driffill[a]	Schmitter[b]	Cameron[c]	Blyth[d]	Bruno-Sachs[e]
1	Austria	Austria	Sweden	Austria	Austria
2	Norway	Norway	Norway	Norway	Germany
3	Sweden	Sweden	Austria	Sweden	Netherlands
4	Denmark	Denmark	Belgium	Denmark	Norway
5	Finland	Finland	Finland	Finland	Sweden
6	Germany	Netherlands	Denmark	New Zealand	Switzerland
7	Netherlands	Belgium	Netherlands	Australia	Denmark
8	Belgium	Germany	Germany	Germany	Finland
9	New Zealand	Switzerland	UK	Belgium	Belgium
10	Australia	US	Australia	Netherlands	Japan
11	France	Canada	Switzerland	Japan	New Zealand
12	UK	France	Italy	France	UK
13	Italy	UK	Canada	UK	France
14	Japan	Italy	US	Italy	Italy
15	Switzerland		France	US	Australia
16	US		Japan	Canada	Canada
17	Canada				US

[a] Source: Calmfors and Driffill (1988). [b] Source: Schmitter (1981). [c] Source: Cameron (1984).
[d] Source: Blyth (1979). [e] Source: Bruno and Sachs (1985).

Table 6: Variable Definitions & Sources for Panel Estimation

CA (% of GDP)	Current account balance, ratio to GDP	IMF World Economic Outlook (2016)
BB (% of GDP)	Government budget balance, ratio to GDP	IMF World Economic Outlook (2016)
Iverson index	Index for wage centralization	Amsterdam Institute for Advanced Labor Studies (AIAS)
Private credit ratio	Ratio of private credit to GDP	World Bank Financial structure database (2011)
GDP growth	measured alternatively by average real GDP-per-capit growth and by changes in GDP-per-capita growth	World Bank World Bank
NFA (% of GDP)	Stock of Net Foreign Assets, ratio to GDP	Lane & Milesi-Ferretti
Relative income	Per capita income, measured relative to the U.S.	IMF World Economic Outlook (2016)
GDP deviation	Deviation of GDP from trend, ratio to GDP ternd	Using the GDP derived from IMF World Economic Outlook (2016)
Population growth	Annual population rowth	World bank
Trade openness	Openness indicator: ratio of exports plus imports of goods to GDP	OECD databasee
Dep. ratio (Old)	Youth dependency ratio, population under 15 relative to the population between 15 and 65	World Development Indicators (2010)
Dep. ratio (Young)	Old dependency ratio, population over 65 relative to the population between 15 and 65	World Development Indicators (2010)
Top 1% and 5% income share	Share of income of the top 1% and 5% of the income distribution	The World Top Incomes Database

Panel consists of Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, UK & the United States.

Table 7: Summary of selected studies of current account balance determinants

	Arabzadeh (Level) (2016)	Arabzadeh (GDP-av deviated) (2016)	Decressin &Starvev (2009)	Cheung C. et al (2013)	Barnes et al (2010)	Chinn &Prasad (2003)	Chinn et al. (2014)
Govt. budget balance	+	+	+	x	+	x	+
Private credit ratio	x	-	x	()	x	x	x
Average GDP growth	x	x	-	x	x	()	x
Net foreign asset	+	+	+	+	+	+	+
Relative income	+	+	+	+	+	+	x
Population growth	-	-	-	()	()	()	()
Trade openness	+	x	x	+	+	x	x
Old depend. ratio	x	-	-	x	x	x	x
Young depend. ratio	x	+	-	x	+	x	x
Countries	16 OECD	16 OECD	11 Euro	30 OECD	25 OECD	18 indus.	23 indus.
Sample	1982-11	1980-12	1970-07	1973-08	1969-08	1971-95	1970-08

+ : Positive effect, significant at least at 10%.
- : Negative effect, significant at least at 10%.
x : Not significant at 10%. () : Not included in the model.

Table 8: Panel Regression, OLS Specification, Level Data

Current account	5-year averages			3-year averages		
	(1)	(2)	(3)	(4)	(5)	(6)
Govt. budget balance	0.267***		0.201**	0.284***		0.252***
	(0.080)		(0.084)	(0.061)		(0.066)
Iverson index		7.889***	6.864**		5.252**	3.503
		(2.889)	(3.039)		(2.672)	(2.627)
Private credit ratio	0.012	0.020**	0.017**	0.013**	0.019***	0.016**
	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)
Δ GDP growth	0.177	0.570	-0.054	0.539	1.518	0.491
	(1.125)	(1.185)	(1.142)	(0.946)	(1.091)	(1.049)
Net foreign asset	0.044***	0.056***	0.053***	0.045***	0.055***	0.049***
	(0.010)	(0.011)	(0.011)	(0.008)	(0.009)	(0.009)
Relative income	3.280**	2.852*	2.296	2.394*	2.053	1.746
	(1.594)	(1.678)	(1.633)	(1.267)	(1.431)	(1.376)
Population growth	-3.224***	-2.920***	-2.836***	-3.431***	-3.107***	-3.333***
	(1.032)	(1.067)	(1.035)	(0.777)	(0.834)	(0.801)
Trade openness	0.025**	0.009	0.010	0.019**	0.013	0.014
	(0.011)	(0.013)	(0.013)	(0.009)	(0.011)	(0.010)
Old dependency ratio	0.038	0.091	0.055	-0.022	0.033	0.004
	(0.105)	(0.108)	(0.104)	(0.083)	(0.096)	(0.092)
Young dependency ratio	0.107	0.183	0.172	0.016	0.018	0.042
	(0.123)	(0.128)	(0.125)	(0.095)	(0.100)	(0.099)
Constant	-6.203	-13.313**	-9.283	-1.971	-7.982	-3.887
	(5.670)	(5.742)	(5.776)	(4.531)	(5.071)	(4.989)
Rsquared	0.65	0.64	0.67	0.61	0.56	0.62
Observations	89	91	89	156	158	153

Standard errors are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9: Panel Regression for Annual Data, OLS Specification

	Including Australia		Excluding Australia	
	(1)	(2)	(3)	(4)
Budget balance	0.218***		0.233***	
	(0.038)		(0.039)	
Iverson index		2.721		5.389**
		(2.358)		(2.410)
Private credit ratio	0.013***	0.018***	0.013***	0.018***
	(0.005)	(0.005)	(0.005)	(0.005)
Δ GDP growth	0.498	1.782*	1.285	2.673***
	(0.820)	(0.979)	(1.004)	(0.986)
Relative income	0.810	0.176	0.674	0.324
	(0.839)	(0.914)	(0.879)	(0.911)
Net foreign asset	0.047***	0.057***	0.046***	0.057***
	(0.006)	(0.006)	(0.006)	(0.006)
Population growth	-2.878***	-2.622***	-3.111***	-2.464***
	(0.499)	(0.546)	(0.526)	(0.561)
Old dependency ratio	0.034	0.070	0.025	0.059
	(0.060)	(0.069)	(0.061)	(0.068)
Young dependency ratio	-0.004	-0.041	-0.021	-0.031
	(0.065)	(0.067)	(0.066)	(0.067)
Constant	-0.787	-4.729	-1.423	-7.606**
	(3.372)	(3.802)	(3.536)	(3.740)
Rsquared	0.53	0.46	0.50	0.47
Observations	443	434	419	422

Standard errors are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 10: Panel Regression for 5% income share

5% income share	5-year averages		3-year averages	
Columns	(1)	(2)	(3)	(4)
Iverson index		-10.734***		-10.090***
		(3.382)		(2.857)
Private credit ratio	0.028***	0.026***	0.026***	0.023***
	(0.007)	(0.007)	(0.005)	(0.005)
Average GDP growth	3.268	3.623**	2.966	3.317**
	(2.095)	(1.465)	(2.025)	(1.308)
Relative income	-2.853*	-3.257**	-2.150*	-2.539**
	(1.611)	(1.577)	(1.145)	(1.170)
Net foreign asset	0.027**	0.024**	0.021***	0.021***
	(0.011)	(0.011)	(0.008)	(0.008)
Old dependency ratio	0.172*	0.181*	0.184**	0.226***
	(0.100)	(0.100)	(0.073)	(0.083)
Young dependency ratio	-0.160	-0.208*	-0.125*	-0.139*
	(0.114)	(0.113)	(0.075)	(0.077)
Constant	14.370**	19.237***	13.401**	16.403***
	(6.911)	(5.972)	(5.731)	(4.778)
Rsquared	0.30	0.61	0.29	0.62
Observations	86	86	149	145

Standard errors are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 11: Panel Regression for 1% income share

1% income share	5-year averages		3-year averages	
Columns	(1)	(2)	(3)	(4)
Iverson index		-3.993		-3.939*
		(2.744)		(2.357)
Private credit ratio	0.019***	0.017***	0.019***	0.016***
	(0.005)	(0.005)	(0.004)	(0.004)
Average GDP growth	2.106	2.252	1.732	1.848
	(1.506)	(1.383)	(1.418)	(1.267)
Relative income	-1.181	-1.131	-1.006	-0.937
	(1.190)	(1.184)	(0.861)	(0.888)
Net foreign asset	0.017**	0.016**	0.011*	0.011*
	(0.008)	(0.008)	(0.006)	(0.006)
Old dependency ratio	0.060	0.072	0.067	0.099
	(0.074)	(0.075)	(0.055)	(0.063)
Young dependency ratio	-0.143*	-0.153*	-0.110*	-0.103*
	(0.084)	(0.084)	(0.057)	(0.058)
Constant	5.341	6.606	4.919	5.380
	(5.041)	(4.895)	(4.127)	(4.050)
Rsquared	0.22	0.32	0.22	0.32
Observations	86	86	149	145

Standard errors are reported in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Table 12: Panel Regression with Inequality, Mean-Deviated Data

Current account	5-year averages			3-year averages		
	(1)	(2)	(3)	(4)	(5)	(6)
Top 5% income	-0.377***			-0.312***		
share	(0.104)			(0.090)		
Top 1% income		-0.357**			-0.329**	
share		(0.152)			(0.139)	
Iverson index		7.629***				6.079***
			(2.747)			(1.987)
Govt. budget	0.178**	0.232***		0.209***	0.254***	
balance	(0.085)	(0.087)		(0.079)	(0.079)	
Private credit	-0.013	-0.019**	-0.017*	-0.022***	-0.027***	-0.015**
ratio	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)	(0.007)
ΔGDP growth	0.828	0.935	0.553	0.237	0.293	0.056
	(0.618)	(0.652)	(0.674)	(0.243)	(0.247)	(0.267)
Net foreign asset	0.071***	0.065***	0.066***	0.064***	0.061***	0.061***
	(0.010)	(0.010)	(0.010)	(0.008)	(0.008)	(0.008)
Relative income	1.883	3.635**	4.696***	2.137	3.022**	4.435***
	(1.652)	(1.602)	(1.603)	(1.323)	(1.311)	(1.230)
Population	-3.792***	-3.665***	-3.657***	-3.683***	-3.661***	-3.799***
growth	(0.930)	(0.974)	(0.976)	(0.750)	(0.769)	(0.731)
Trade openness	-0.004	0.004	-0.006	-0.011	-0.007	0.001
	(0.012)	(0.012)	(0.013)	(0.010)	(0.010)	(0.009)
Dep. ratio	-0.298**	-0.303**	-0.232*	-0.295***	-0.320***	-0.257***
(Old)	(0.117)	(0.123)	(0.124)	(0.101)	(0.105)	(0.097)
Dep. ratio	0.171	0.124	0.185	0.154	0.124	0.147*
(Young)	(0.110)	(0.114)	(0.115)	(0.094)	(0.096)	(0.086)
Constant	-2.196	-3.679**	-5.989***	-2.305*	-3.069**	-5.333***
	(1.517)	(1.516)	(1.529)	(1.263)	(1.288)	(1.131)
Rsquared	0.71	0.69	0.66	0.65	0.63	0.60
Observations	83	83	85	141	141	147

Standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 13: Panel Regression with Inequality Effect, Level data

Current account	5-year averages			3-year averages		
	(1)	(2)	(3)	(4)	(5)	(6)
Top 5% income share	-0.015			0.035		
	(0.107)			(0.084)		
Top 1% income share		0.207			0.278**	
		(0.160)			(0.124)	
Iverson index			7.789***			5.693**
			(2.527)			(2.235)
Govt. budget balance	0.299***	0.298***		0.296***	0.295***	
	(0.092)	(0.090)		(0.066)	(0.063)	
Private credit ratio	0.014	0.015*	0.016**	0.012*	0.013**	0.015**
	(0.009)	(0.009)	(0.008)	(0.007)	(0.006)	(0.007)
ΔGDP growth	0.053	-0.273	0.406	0.328	0.148	1.306
	(1.248)	(1.230)	(1.005)	(0.930)	(0.864)	(0.890)
Net foreign asset	0.046***	0.041***	0.054***	0.047***	0.041***	0.055***
	(0.012)	(0.011)	(0.010)	(0.009)	(0.008)	(0.008)
Relative income	2.686	2.930*	3.362**	2.597*	2.851**	2.772**
	(1.813)	(1.730)	(1.565)	(1.342)	(1.236)	(1.321)
Population growth	-2.913**	-3.191***	-2.803***	-3.045***	-3.473***	-2.934***
	(1.151)	(1.164)	(1.054)	(0.833)	(0.827)	(0.832)
Trade openness	0.026*	0.032**	0.017	0.024**	0.032***	0.018
	(0.015)	(0.015)	(0.014)	(0.011)	(0.011)	(0.011)
Dep. ratio (old)	0.066	0.067	0.083	0.011	-0.000	0.056
	(0.114)	(0.114)	(0.104)	(0.088)	(0.084)	(0.091)
Dep. ratio (young)	0.109	0.169	0.175	0.044	0.092	0.050
	(0.135)	(0.137)	(0.121)	(0.097)	(0.095)	(0.095)
Constant	-6.066	-9.623	-13.073**	-4.235	-6.983	-9.684**
	(6.706)	(6.525)	(5.244)	(4.909)	(4.629)	(4.567)
Rsquared	0.65	0.64	0.65	0.62	0.64	0.59
Observations	80	80	85	141	141	147

Standard errors are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 14: Estimation for Households Private Saving, Cross-sectional deamining

Household Saving	3-year averages				5-year averages			
	No fixed-effect		with fixed-effect		No fixed-effect		with fixed-effect	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Govt. budget	-0.398***		-0.286***		-0.342***		-0.277**	
balance	(0.100)		(0.095)		(0.126)		(0.118)	
Top 5%	-0.398***		-0.504***		-0.539***		-0.796***	
income share	(0.133)		(0.144)		(0.194)		(0.225)	
Iverson index		-6.657		-4.517		-6.034		-6.454
		(4.444)		(5.786)	(5.769)			(7.785)
Priv. credit	-0.042***	-0.040***	-0.050***	-0.047***	-0.036***	-0.037**	-0.048***	-0.044***
ratio	(0.010)	(0.010)	(0.009)	(0.010)	(0.014)	(0.015)	(0.014)	(0.015)
NFA	0.069***	0.058***	0.055***	0.048***	0.077***	0.060***	0.065***	0.050**
	(0.012)	(0.012)	(0.013)	(0.013)	(0.018)	(0.018)	(0.020)	(0.021)
Relative income	1.873	0.465	2.863*	1.594	1.546	2.167	2.250	3.456
	(1.742)	(1.839)	(1.666)	(1.814)	(2.630)	(2.676)	(2.575)	(2.755)
ΔGDP growth	-0.089	0.259	-0.003	0.274	0.881	1.178	1.301*	1.506*
	(0.290)	(0.285)	(0.258)	(0.262)	(0.840)	(0.906)	(0.755)	(0.849)
Dep. ratio	-1.012***	-0.958***	-0.969***	-0.924***	-0.989***	-0.909***	-1.016***	-0.850***
(Old)	(0.134)	(0.156)	(0.130)	(0.158)	(0.193)	(0.209)	(0.192)	(0.217)
Dep. ratio	0.083	0.179	0.405**	0.533***	-0.028	0.018	0.301	0.529*
(Young)	(0.168)	(0.176)	(0.180)	(0.188)	(0.231)	(0.246)	(0.255)	(0.277)
Population	0.169	-1.116	0.278	-0.582	1.730	0.773	2.584	2.485
growth	(1.043)	(1.081)	(1.017)	(1.061)	(1.570)	(1.662)	(1.571)	(1.699)
Constant	-2.801	1.664	-4.670***	-0.206	-3.283	-0.278	-5.213**	-1.202
	(1.799)	(2.424)	(1.596)	(2.715)	(2.623)	(3.255)	(2.436)	(3.793)
Observations	137	141	137	141	81	83	81	83
Overall R-squared	0.54	0.19	0.11	0.07	0.25	0.18	0.09	0.05
Within R-squared	0.29	0.49	0.57	0.51	0.58	0.48	0.62	0.52

Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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