Financial Incentives for

Low Carbon Investment

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Abstract

Policymakers at European, national, and regional levels of governance have formulated low carbon objectives to tackle climate change. Previous studies have identified numerous market barriers preventing a shift in investment from carbon intensive to low carbon technologies. In order to overcome these barriers, policymakers have implemented pricing, regulatory and information based instruments. The implementation of this policy mix raises a multitude of questions related to its effectiveness in delivering decarbonisation across sectors. This thesis aims to inform two of these debates that have not been widely studied yet: reforming the European Emission Trading System (EU ETS) to trigger low carbon investments and using grants and subsided loans to unlock private investment in energy efficiency. Its focus is on the role of these policy instruments in creating financial incentives for low carbon investments. First, this thesis addresses the question of how the volume of surplus allowances in the EU ETS impacts firms' banking strategies and associated discount rates. It quantifies the surplus and models strategies of market participants to invest in CO_2 allowances as identified in interviews. The findings show that the power and industry sectors hold the majority of allowances to hedge future production; additional surplus allowances must be banked by speculative investors who require higher rates of return. Then this thesis addresses the role of grants and subsidised loans in triggering low carbon investments in non-EU ETS sectors by concentrating on the intermediaries who implement these policy instruments. Thus, the question is examined to what extent the EU budget policy process sets incentives for regional policymakers to adjust their programmes and use EU funds for European low carbon objectives. Interviews demonstrate that requiring policymakers to specify financially binding priority axes that are in line with the EU energy and climate targets can be effective to integrate these objectives into the decision making process at regional level. Furthermore, it can be seen that the effectiveness depends on the funding criteria that the policymakers can choose freely, once the programmes have been approved by the European Commission. Finally, commercial banks' incentives to provide capital to energy efficiency investments as identified in interviews are modelled. The findings illustrate the need for banks to reach a certain scale in energy efficiency lending to overcome initial transaction cost and to benefit from portfolio diversification. Achieving this scale of energy efficiency lending poses challenges that policy support can help to overcome, for example by catalysing the market development with technical assistance or preferential loans.

Keywords: Decision making modelling; Banking; Discount rates; Emission trading schemes; Surplus allowances; EU budget; Policy process; Regional programmes; Commercial banks; Energy efficiency lending; Portfolio diversification; Transaction cost

Zusammenfassung

Zur Bekämpfung des Klimawandels haben politische Entscheidungsträger auf europäischer, nationaler und regionaler Regierungsebene CO_2-Reduktionsziele formuliert, die erhebliche Investitionen erfordern. Studien haben zahlreiche Marktbarrieren ermittelt, die diese Investitionen verhindern. Zur Überwindung dieser Barrieren wurden regulatorische, preis- und informationsbasierte Politikinstrumente implementiert. Bei der Umsetzung ergeben sich eine Vielzahl von Fragen im Hinblick auf die Effektivität dieser Instrumente, die gesteckten Ziele zu erreichen. Zwei bislang wenig erforschte Instrumente greift diese Dissertation auf: die Reformierung des Europäischen Emissionshandelssystems um kohlenstoffarme Investitionen zu fördern und die Verwendung öffentlicher Gelder zur Verbesserung der Energieeffizienz. Im Zentrum stehen dabei die Politikinstrumente und ihre Möglichkeiten, durch finanzielle Anreize kohlenstoffarme Investitionen zu stimulieren. Zunächst wird die Frage untersucht, wie das Volumen der überschüssigen Zertifikate im Emissionshandelssystem die Banking-Strategien der Marktteilnehmer und die dazugehörigen Diskontierungsraten beeinflusst. Anhand von Interviews mit Marktteilnehmern werden deren Banking-Strategien modelliert und der Überschuss quantifiziert. Die Ergebnisse zeigen, dass die Strom- und Industriesektoren den Großteil der überschüssigen Zertifikate halten um ihre prognostizierte Produktion abzusichern; darüber hinaus gehende Überschüsse müssen von spekulativen Investoren mit höheren Ertragsraten gehalten werden. Anschließend wird die Rolle von Zuschüssen und vergünstigten Darlehen zur Förderung kohlenstoffarmer Investitionen in nicht-EU ETS Sektoren analysiert. Dabei liegt der Fokus auf politischen Entscheidungsträgern und Banken, da sie als Intermediäre von zentraler Bedeutung für die Implementierung der Instrumente sind. So wird untersucht, inwieweit die Finanzierungspolitik des EU-Haushalts Anreize für politische Entscheidungsträger auf regionaler Ebene setzt, ihre Gelder in Einklang mit europäischen Zielen zu verwenden. Interviews zeigen, dass die Festlegung von finanziell verbindlichen Prioritätsachsen für die EU-Klima- und Energieziele ein effektives Instrument ist, um diese Ziele in den Entscheidungsprozess auf regionaler Ebene zu integrieren. Gleichzeitig wird deutlich, in welch hohem Maße die regionalen politischen Entscheidungsträger die Effektivität beeinflussen können, da sie nach der Genehmigung der EU-finanzierten Programme durch die Europäische Kommission weitgehend freie Hand haben bei deren Umsetzung. Abschließend werden anhand von Interviews mit Bankern deren Anreize modelliert, Darlehen für Energieeffizienz zu vergeben. Die Ergebnisse illustrieren die Notwendigkeit für Banken, einen gewissen Skaleneffekt zu erzielen, um die anfänglichen Transaktionskosten zu überwinden und um von der Portfoliodiversifizierung zu profitieren. Technische Unterstützung oder Förderdarlehen können zur Beschleunigung der Marktentwicklung beitragen.

Schlüsselwörter: Entscheidungsprozessmodellierung; Banking; Diskontierungsrate; Emissionshandelssystem; Überschusszertifikate; EU-Haushalt; Politikprozess; Regionale Programme; Kommerzielle Banken; Energieeffizienz-Darlehen; Portfoliodiversifizierung; Transaktionskosten

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I dedicate this thesis to my family and to Stefano.

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1. Introduction

This thesis aims to provide an evidence base for the role of selected policy instruments, namely emissions trading, grants and subsidised loans, in creating financial incentives for low carbon investments by investigating and modelling the decision making of public and private actors.

1.1 Motivation

Tackling climate change in Europe requires reducing carbon emissions in energy producing and energy using sectors, above all in the power, buildings, industry, and transport sectors. This requires a shift in investments from carbon intensive technologies towards low carbon technologies in these sectors, in particular towards investments to increase the share of renewables in the energy mix and to improve energy efficiency both on the demand and supply side.

To address climate change, policymakers at European, national, and regional levels of governance have formulated various low carbon objectives and strategies. The European Union (EU) heads of state committed to the Europe 2020 climate and energy package. In doing so, they set three targets: a 20% reduction in greenhouse gas emissions compared to 1990 levels, a 20% share of renewables in energy consumption, and a 20% reduction in primary energy use through energy efficiency improvements (EU, 2008a). In the long run, limiting climate change to 2°C necessitates decarbonising the economy. The European Commission has set out roadmaps to decarbonise across sectors with the overall aim of reducing emissions by 80-95% from their 1990 levels by 2050 (EU, 2011c; EU, 2011d). Furthermore, the European leaders are discussing intermediate targets for 2030.

Taking into account the current emission trends, the EU is not likely to achieve its long term targets (EU, 2011c). Previous studies point to numerous market failures and other barriers that prevent markets from decarbonising the economy (IPCC, 2007): Without adequate policies, external cost from carbon emissions are not priced in economic activities leading to too many emissions and too few investments in low carbon technologies (Jaffe et al., 2005). Incomplete information is another frequently cited cause for market failure. Information asymmetries and split incentives between landlords and tenants can prevent investments in energy efficiency or renewables (Schleich and Gruber, 2008). High investment cost, low awareness of potential benefits, ignorance or inertia by firms and households are further examples of barriers inhibiting investment in low carbon technologies (Carbon Trust, 2005). As a consequence, markets alone will not attain these targets and therefore a mix of policy instruments is needed to overcome the various barriers (Goulder and Parry, 2008).

To achieve the targets discussed above, policymakers put pricing, regulatory and information based instruments in place. The implementation of this bouquet of policy instruments raises a multitude of questions related to their effectiveness in delivering decarbonisation across sectors. This thesis aims to contribute to two recent debates: reforming the European Emission Trading System (EU ETS) to trigger low carbon investments and using grants and subsided loans to unlock private investment in energy efficiency.

The EU ETS is one of the key instruments to guide firms' investment decisions toward low carbon technologies by increasing the cost of carbon intensive technologies and enhancing credibility of future emission reduction targets. However, the surplus of CO_2 allowances, which has accumulated primarily as result of the economic crisis and the import of offsets, has caused some to question the effectiveness of the scheme and triggered policy and scientific debate about structural reforms of the EU ETS.

The debate about unlocking private investment in energy efficiency has been reinforced through the EU Energy Efficiency Directive and the 2014-2020 EU budget. The Directive stipulates that member states develop long term strategies to guide investment decisions of individuals, the construction industry and financial institutions in building renovations as part of the National Energy Efficiency Action Plans. Furthermore, the Directive encourages the member states to use the EU Structural and Cohesions Funds to trigger energy efficiency investments (EU, 2012b). The EU budget is the financial vehicle at European level to attain common objectives. 20% of the 2014-2020 budget is attributed to the EU energy and climate targets (EU, 2011b). In addition, member states dedicate national budgets to incentivise low carbon investments by the private sector. In Germany, the Kreditinstitut für Wiederaufbau (KfW), the national public bank, is the main financing institution to provide subsidised loans and grants for energy efficiency as well as renewable energy technologies (Jürgens et al., 2012).

To be effective, the policy instruments implemented must collectively allow European policymakers to achieve their set targets. In this context, one important aspect of policy implementation is to what extent incentives and requirements of public and private actors are in line with the target regime and allow for the desired low carbon investments. This aspect has not been widely studied and therefore motivates this thesis to provide an evidence base for decision making in order to inform the respective policy and scientific debates.

1.2 Research Question

The purpose of this thesis is to examine the role of selected policy instruments, namely emissions trading, grants and subsidised loans, in creating financial incentives for low carbon investments by public and private actors. The targets formulated by policymakers serve as benchmark. The focus is on the following four related, but independent research questions:

The second and third chapters analyse the functioning of the EU ETS. The effectiveness of this instrument in encouraging low carbon investments has been reduced by a large surplus that has not found investors who value the CO_2 allowances sufficiently highly to maintain previous carbon price levels. This raises the question addressed in chapter 2 of how the volume of surplus allowances impacts the strategies adopted to bank these allowances and the associated risk return requirements of the various actor groups. Chapter 3 is closely related to this question by analysing the impact of banking strategies used by power firms and financial speculators on carbon price developments. The fourth and fifth chapters address the role of grants and subsidised loans in triggering low carbon investments in non-EU ETS sectors. The focus, however, is on the intermediaries rather than on the final beneficiary, as they play a crucial role in implementing these policy instruments. Chapter 4 aims to answer to what extent the EU budget policy process provides regional policymakers with incentives and requirements of adjusting regional strategies and using EU funds for low carbon investments. Chapter 5 examines the incentives and requirements of commercial banks to provide capital for energy efficiency investments, and seeks to explore how initially higher perceived risk and higher transaction cost can be managed with policy support.

1.3 Research Methodology

In order to address these questions, two types of methodologies are combined: microeconomic models and expert interviews. To assess decision making by firms and banks, the third and fifth chapters make use of small scale microeconomic modelling. In these models, both firms and banks follow rational choices considering risk management and regulatory constraints. As data availability on their decision making is thin, the analysis in all four chapters is informed by interviews with the respective expert groups. The interviews were semi-structured; they followed an interview guideline including both open and quantitative questions. The experts were chosen based on purposive sampling. Thus, the sample includes the European power firms with the greatest power share, the German policymakers that manage EU budget programmes and the largest banks by total assets and energy efficiency lending expertise. The sample sizes of 20-30 experts do not allow for representative conclusions, but provide insights into aspects of decision making that are crucial for designing and implementing policy instruments effectively.

Chapter 2 quantifies the surplus of CO_2 allowances in the EU ETS and the volumes that are banked by different groups of market participants between 2008 and 2012 and projects them until 2020. Based on this demand and supply balance, the impact of various policy options on the surplus is estimated. Chapter 3 models the hedging behaviour by the power sector as a function of the carbon price structure and risk management strategies reported by power firms. This partial equilibrium analysis is then integrated into a CO_2 demand and supply model considering also demand by emitting firms and speculative investors. In order to analyse the decision making by policymakers, chapter 4 uses a more qualitative approach by examining the incentives and requirements related to the policy process of the EU budget beyond utility maximisation. Chapter 5 models banks' incentives and requirements related to energy efficiency lending as identified in interviews. A detailed description of the methodology can be found in the respective chapters.

1.4 Findings

The main findings of each individual chapter are summarised in the points that follow.

Chapter 2 examines the different actor groups that bank the allowance surplus and their incentives to do so. In the first trading period prices dropped to zero, as supply exceeded demand and market participants could not bank allowances for future use. In the second trading period prices did not drop to zero, despite a surplus that has accumulated since 2008 and is estimated to grow to 2.6 billion tonnes of CO_2 by 2015. This is due to the fact that surplus allowances can be banked for future trading periods. However, interviews with market participants point to a limited capacity to bank allowances. Thus, firms in the power and industry sectors reported to hold the volume of surplus allowances that they need in order to hedge future emissions. As CO_2 allowances do not create any storage cost, banks can buy CO_2 allowances at the spot market and offer forward contracts to hedging firms at a modest price that covers their opportunity cost of capital. Any additional surplus requires the involvement of speculative investors. It was reported that the latter only enter the market when current prices drop to levels that promise large price increases in forthcoming years. As a consequence, an increase in surplus allowances not only results in price reductions linked to reduced scarcity, but can further depress current prices, owing to the higher discounts applied to carbon price expectations. This in turn reduces the impact of the cap-and-trade scheme on the strategic and investment choices adopted by firms. In this chapter, policy options to align the cap more closely with the actual emission trajectory are discussed.

Chapter 3 extends the analysis on the EU ETS by modelling the interaction between emitters, hedgers and speculators in a CO_2 demand and supply framework. In interviews, power firms reported that they hold allowances to hedge the cost of CO_2 allowances when they sell power several years ahead in order to comply with corporate risk management procedures. However, the volume of power sold forward as well as the allocation to different generation assets is adjusted according to deviations of forward prices from firms' expectations. If a power firm expects the CO_2 price to significantly exceed the price at which forward contracts are traded, then it will increase the total power hedging volume and also increase its share of carbon intensive generation assets used to hedge. This allows the firm to profit from the expected increase in carbon prices over time. It is estimated that such individual adjustments could result in an overall CO_2 hedging volume in the range of 1.1 to 1.7 billion allowances by the end of 2012 at discount rates of carbon price expectations between 0 to 10%. Since the cumulative surplus in the EU ETS exceeds this hedging volume, the impact of CO_2 banking by speculative investors is also considered. In a two period CO_2 demand and supply model, we demonstrate that as the surplus in the EU ETS increases, the discrepancy between forward prices and price expectations gradually widens and the discount rates applied to carbon price expectations increase. This underlines the value of reducing the surplus in order to ensure that hedgers can absorb excess supply.

Chapter 4 analyses to what extent the EU budget process creates incentives and requirements for German regional policymakers to shift their regional strategies away from existing priorities in the area of transport or general business support towards new priorities such as renewable energy or energy efficiency. One fifth of the 2014-2020 EU budget is attributed to the European energy and climate targets. Experience gleaned from the 2007-2013 EU funded programmes shows that the strategy formulation is crucial to integrate European objectives in the regional decision making process. In this process step, regional policymakers allocate funds to thematic priorities using two unlinked accounting systems, priority axes and expenditure categories. The allocation of the EU budget under the Regional Development Fund can create incentives to counteract risk aversion and inertia, insofar as it requires policymakers to specify a financially binding priority axis that reflects the EU climate and energy objectives, if they wish to qualify for access to the budget. After programme approval, the regional ministries are flexible in its implementation and the selection criteria that they apply. The monitoring process can balance the incentives for regional policymakers to use EU money flexibly, in response to market and policy developments during the seven year budget framework, as well as prioritise disbursement of the money over the delivery of policy objectives.

Chapter 5 investigates the incentives and requirements of commercial banks for providing energy efficiency lending. Using Germany, Bulgaria, Poland and Ukraine as case studies, interviews were conducted with banks in order to model their decision making related to energy efficiency. The findings show that energy efficiency investments differ from other lending projects for three reasons. First, asymmetric information and principal agent problems prevent energy efficiency investments. To overcome these barriers, many public banks provide energy efficiency lending often through commercial banks. Commercial banks reported that this allows them to gain customers. Second, energy efficiency lending is a new field of investment with unconventional revenue streams deriving from cost savings. Energy savings increase the value of the object that serves as collateral and diversify the lending portfolio. However, most banks reported that they do not consider energy efficiency specifics. Third, assessing these energy savings requires additional technical expertise. In Bulgaria, Poland and Ukraine, the European Bank for Reconstruction and Development (EBRD) employs a technical assistance team that trains bankers and supports them in developing the project pipeline. In Germany, KfW, the national public bank, allocates the energy saving assessment to certified energy service providers in order to reduce transaction cost for intermediary banks. The analytic model illustrates the trade-off banks face between initial transaction cost for demand development and benefits from portfolio diversification and associated lower equity requirements. According to these findings two aspects are important to upscale energy efficiency lending: first, the requirement for banks to monetise energy savings to account for the benefit of low risk in the lending portfolio and, second, the need for energy efficiency programmes to reach a certain scale so that energy efficiency lending pays off.

Unifying conclusions of the four chapters and resulting perspectives for further research are presented in the final chapter.

2. How do surplus allowances impact banking behaviour?

Karsten Neuhoff, Anne Schopp, Alexander Vasa, Kateryna Stelmakh, Rodney Boyd

In cap-and-trade schemes, the banking of surplus allowances allows flexibility across time, enhancing the efficiency of mitigating carbon emissions. We find that the European experience points to the limited capacity of banking. This is due to the fact that the power and industry sectors hold surplus allowances to hedge future emissions. Any additional surplus requires the involvement of speculative investors. The latter only enter the market when current prices drop to levels that promise large price increases in forthcoming years. As a consequence, any increase in surplus allowances does not simply result in price reductions linked to reduced scarcity, but can further depress current prices, owing to the higher discounts applied to carbon price expectations. This in turn reduces the impact of the scheme on the investment choices adopted by firms. We discuss policy options in order to align the cap more closely with the actual emission trajectory.

Keywords: Banking; Discount rates; Emission trading schemes; Surplus

2.1 Introduction

Cap-and-trade schemes employed to reduce carbon emissions create flexibility in targeting least cost mitigation opportunities across installations and across time. Market participants are incentivised to accelerate cost efficient mitigation efforts since additional allowances can be banked for use in a future period (Phaneuf and Requate, 2002). As the environmental damage of carbon is linked to the stock of cumulative emissions, any additional mitigation either reduces damage or avoids the need for more costly mitigation efforts at a later date and therefore is welfare enhancing. The benefits of this flexibility are confirmed in empirical studies by Ellerman et al. (2007) for the US Acid Rain Programme, while other studies demonstrate the welfare losses linked to regulatory provisions constraining banking between the first and the second trading period of the EU ETS (Alberola and Chevallier, 2009).

In theory, with banking carbon prices follow Hotelling's rule and so increase in line with the rate of interest (Rubin, 1996). Based on this theory, academic analysis and government assessment of emission trading schemes assume that surplus allowances are banked at discount rates of the order of 3-5% (Ellerman et al., 2007; EU, 2008b; DECC, 2009).

We explore under which conditions this assumption is applicable. We therefore quantify the annual supply of allowances to the market and the demand by emitters since 2008 and project it up to 2020. Since supply has continuously exceeded demand, a surplus has accumulated, linked primarily to 0.7 billion tonnes of lower CO_2 emissions during the economic crisis and an unexpectedly large supply of 1.7 billion international project credits.

The carbon price is observed to drop in line with the increase in the cumulative surplus. This could be explained by two drivers. First, an increase in the current surplus leads to a decline in the expectation of future scarcity. As a result the carbon price expectations decline, and the current price declines accordingly. Second, an increase in the surplus implies that market participants need to bank more allowances or that new market participants need to start banking allowances. If (new) market participants require higher rates of return in order to bank allowances, they will only enter the market once the current price declines to a level that allows for such returns in subsequent years.

While the first driver is generally recognised, we examine whether the second driver, higher discount rates applied to carbon price expectations have also contributed to a decline in prices. We therefore interviewed market participants on the strategy they pursue in holding CO_2 allowances, and classified them into three categories (Bailey, 2005): arbitrage, hedging and speculation.

The results show that with the phasing out of the free allowance allocation, the power sector increased its holding of CO_2 allowances or forward contracts on CO_2 allowances to about 1.4 billion tonnes by 2012 to hedge against the uncertainty of CO_2 prices when selling power on longer-term arrangements. Schopp and Neuhoff (2013) estimate that individual adjustments of power firms to the carbon price structure can in aggregate result in a hedging corridor of 1.1

to 1.7 billion tonnes CO_2.

Banks reported that they often facilitated such transactions, buying allowances and selling forward contracts on CO_2 allowances. As allowances can be stored at zero cost and banks are not exposed to the carbon price risk, the opportunity cost of capital and some level of counterparty risk determine the discount rate implicit in such transactions. In effect, forward prices were on average traded 5% above the spot trade in the second trading period (EEX, 2012). Moreover, the industry sector retained some of the surplus allocation to hedge against future exposure.

According to our estimates, the surplus in the market, however, has exceeded banking volumes by the power and industry sectors. Additional actors are therefore required to bank surplus allowances, typically speculative financial investors. Both interviews with market participants of the EU ETS and experience in other commodity markets demonstrate that speculative investors will only acquire allowances providing they expect an annual rate of return in excess of 10-15%. Therefore, once the cumulative surplus of allowances exceeds the use of these allowances by the power and industry sectors, the allowance price drops until the return requirements of speculative investors are met leading them to participate in the banking of surplus allowances. We find that the decline of the CO_2 allowance price corresponds to the moment when the surplus of allowances actually exceeded the hedging volumes held by the power and industry sectors. This is consistent with the argument that the discounting of carbon price expectations has increased as a result of the increased surplus.

The analysis of the banking capacity in the market raises the question as to whether a higher discount rate applied to expectations on future carbon prices should be of concern for the design of a cap-and-trade mechanism. For most investors the current carbon price is of relevance because forward contracts are only actively traded for a couple of years and so carbon prices for 2020 are difficult to derive from markets. As a consequence, the current carbon price is used as the basis for the strategy and investment choices made by firms (Martin et al., 2011). This means that efforts to decarbonise through low carbon investment might be insufficient, as well as inefficient where current prices are lowered by the higher discount rates sought by speculators.

If cap-and-trade mechanisms are to avoid such outcomes, they need to be designed so that the emission cap more closely matches the envisaged emission trajectory. This will limit the cumulative surplus of allowances that accrues over time. However, even a carefully designed emission cap requires a mechanism able to react robustly to any unexpected (emission) developments. Our analysis suggests that banking provides less flexibility for absorbing large surpluses than has been previously assumed. Further analysis is required to understand whether the remaining flexibility is sufficient to deliver stable carbon prices, or whether complementary policy options are warranted, including reserve prices for allowance auctions (California and the North-eastern US states), shorter commitment periods (Australia, California and the North-eastern US states) or even automatic adjustments of the surplus as proposed by the European Commission (EU, 2013).

The remainder of the paper is structured as follows: Section 2 quantifies the surplus of allowances in the EU ETS. Section 3 quantifies the banking volumes of allowances by the power, industry and finance sectors and analyses their required incentives for CO_2 banking. Section 4 uses the demand-supply balance to discuss implications for CO_2 pricing and policy options to inhibit large surpluses in the EU ETS. Section 5 summarises the main findings.

2.2 Accumulation of CO_2 surplus

A surplus of allowances in the EU ETS has accumulated since 2008 and is expected to continue growing. The surplus results in part from the financial and economic crisis, as carbon emissions fell below expectations at the time the emissions cap was set and there was also an unexpectedly large supply of international project credits. The volume of surplus allowances derives from the difference of inflows in the EU ETS (free allocation, auctions, and international offsets) and outflows (use of allowance for compliance purposes). This surplus is a stock carried over into future periods. We have analysed each component in detail in order to quantify the surplus:

Cap

The emissions cap in the second trading period, between 2008 and 2012, is made up of allocations established in the National Allocation Plans. These amounted to 2.1 billion tonnes of CO_2 per year (Vasa and Neuhoff, 2010). In 2012, the inclusion of aviation increased the cap by 215 million tonnes of CO_2. From 2013, the cap includes both aviation and new sectors, and decreases by 37 million tonnes of CO_2 each year until 2025, at which time the reduction in the cap is up for review (EU, 2009).

Timing of Auctions

In addition to the regular auctions, between 2011 and 2013 a volume of 350 million allowances not previously issued in the second trading period for new installations has and is being auctioned. This effectively increases the cumulative surplus of allowances in the market. Furthermore, the European Commission has allocated 300 million allowances of the New Entrant Reserve (NER) for the third trading period, between 2013 and 2020, to the European Investment Bank, in order to secure technology funding for carbon capture and storage and renewables. The European Investment Bank is selling future derivative contracts against these 300 million CO_2 allowances in several tranches from 2011 to 2013 (EU, 2012a). Finally, 120 million allowances of the third trading period were auctioned in 2012 reducing the volume to be auctioned to the power sector in 2013 and 2014 by 60 million in each year (EU, 2010a).

Offsets

The additional supply of allowances derives from the importing of international offset credits into the EU ETS. Market participants can import up to 1.68 billion credits from the Clean Development Mechanism (CDM) and Joint Implementation (JI) projects (Vasa et al., 2010).

Based on registered projects that are linked to EU buyers in project documentation, we estimate that the import quota will be filled by 2015.

By the end of 2012, actual issued credits from the CDM and JI linked to EU buyers amounted to 1.18 billion (IGES, 2013; UNEP Risoe, 2013). In addition, 3839 of a total of 5381 CDM and all 576 JI projects have been registered and are sponsored by the 27 EU member states, Norway, Iceland, Liechtenstein and Switzerland. The exclusion of industrial gas credits (HFC and N_2O) and projects from China or India from EU ETS after 2012 is reflected in our estimate. Credits issued prior to 2008 are allocated to the year 2008. In order to assess the maximum supply of credits from registered projects, we are assuming the successive renewal of crediting periods.

The expected credit supply available to EU buyers is dependent on issuance success. Between 2008 and 2012, industrial gas projects had an issuance success rate of 92%. The issuance rate for non-industrial gas projects was 26% in the same period. This may be partly explained by the low carbon offset prices that encouraged market participants not requiring immediate credits for sale or use to delay the costs of auditing by delaying issuance. This also enables them to combine the auditing for several years, further reducing costs. We are assuming therefore that the rate of issuance will increase to 50%, should the value of offsets that can be imported into the EU ETS increase with allowance prices. In this case the import quota will be filled by 2015. Should the issuance rate remain at 26%, the import quota will be achieved about two years later. If it exceeds 50%, then the import quota could already be met by 2014. Our estimate does not account for new project registrations in least-developed countries for the CDM and JI in general. If we account for these, issued credits would fill the import quota earlier, assuming full issuance of CDM projects in least-developed countries.

In interviews, we were unable to identify to what extent power generators will be able to use expected, but as yet unissued, credits from registered projects to hedge carbon use for forward power sales. If, for example, expected credits to be issued from a wind project can be used as a hedge, then the supply to the market at any point would exceed the actual number of credits issued, and the import quota would be met even earlier.

Emissions

Emissions covered by the EU ETS amounted to about 2 billion tonnes of CO_2 per year for the period 2008 to 2010 (CITL, 2011). Emissions projections for the period 2011 to 2020 are based on the European Commission Current Policy Initiative Scenario as specified in the Energy Roadmap 2050 (EU, 2011e). This scenario includes both emissions by aviation and new sectors. The assumed carbon price is 15 Euro/ tonne of CO_2 in 2020. For comparison purposes we also use the Reference Scenario which considers climate policies implemented by March 2010 and the High Renewables Scenario which assumes additional policies for promoting energy efficiency and renewable energy.

Evolution of surplus

Figure 2.1 shows the cumulative surplus of CO_2 allowances resulting from the difference between supply and emissions since 2008 and projected until 2020.

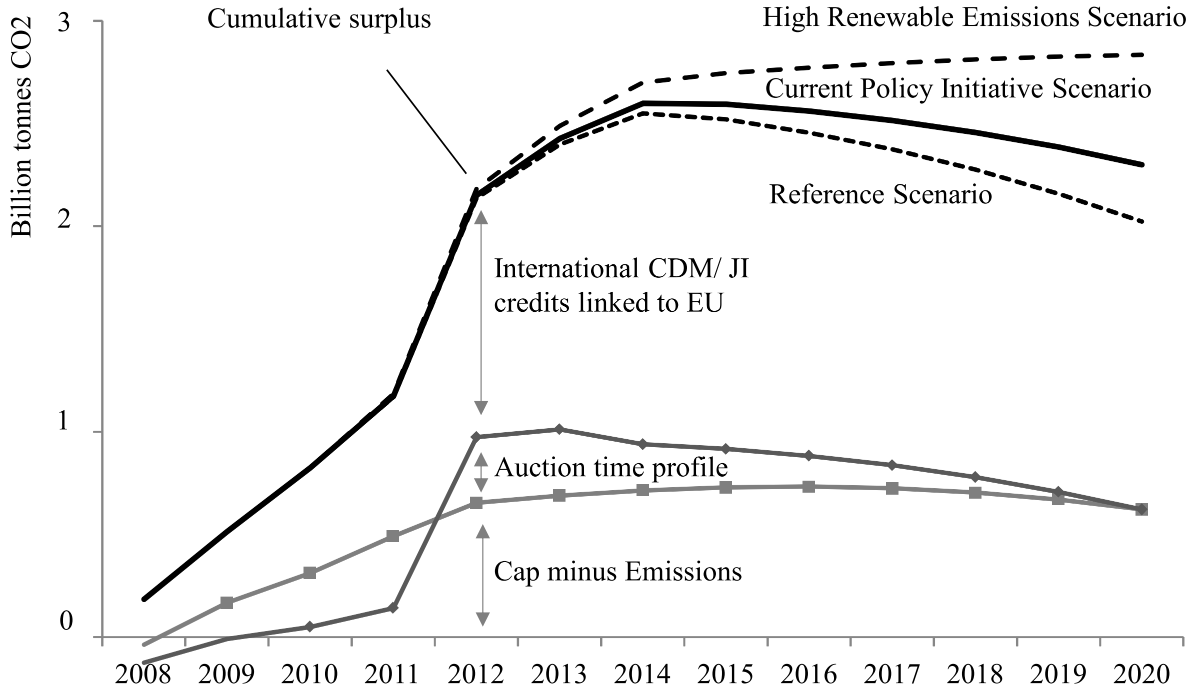

Figure 2.1: Cumulative surplus of CO_2 allowances in the EU ETS
Sources: Based on CITL (2011), EU (2009), EU (2011e), IGES (2013), UNEP Risoe (2013)

According to our calculations the cumulative surplus of allowances will continue to grow; peaking at 2.6 billion tonnes of CO_2 in 2015 before falling slowly at a rate which depends on the future emission trajectory.

2.3 Quantification of CO_2 banking

Despite this surplus, the price did not drop to zero in the second trading period. This implies that market participants are banking these surplus allowances. We can identify three principle sectors that bank allowances: the power, the industry and the finance sector. To address the initial question as to whether the size of banking impacts on the discount rates applied to carbon price expectations, we analyse the factors that impact on the banking strategies of these three sectors. Since the net positions of different actors have not been reported, we conducted a series of semi-structured interviews (Rubin and Rubin, 2005; Manheim et al., 2012) to investigate the following questions:

- Under what conditions do actors hold allowances beyond compliance needs?
- What factors inform the decision to hold or sell allowances?

- What is the role of CDM and JI credits for banking?
- What discount rates do actors require to hold allowances as open positions?
- How has the banking strategy changed in the last three years?
- What factors could contribute to a change in banking strategy?

We identified 50 actors who play an important role in the EU ETS in terms of emissions or CO_2 trading. Of these, 21 experts from the power, industry and finance sectors shared their experience on CO_2 banking strategies within their firms and sectors between November 2011 and January 2012. We use publicly available data on CO_2 banking to complement our findings.

In the following section, we characterise the different incentives and strategies employed by the power, industry and finance sectors to bank, and then quantify the banking volumes of surplus EU ETS allowances.

2.3.1 Power sector

In interviews, power generators reported that they bank allowances to hedge sales of power, which they pursue one to three years ahead of production. To secure the cost for the inputs required for generating the power, they sign contracts in parallel for fuels and CO_2 allowances. This means power generators hold allowances beyond compliance needs to hedge carbon for future use. Until 2012 power generators received most of their allowances free of charge and, consequently, did not need to hedge the carbon required for future power sales. After 2012, however, power generators in Western Europe no longer received free allowances and needed to hedge the price for acquiring these allowances, which explains why the hedging volume has gradually increased since 2008.

Power generators also reported that they have some flexibility on the amount of hedging they undertake, linked to changes of the carbon intensity of production and to flexibility within the hedging strategy. First, the carbon intensity of power production can change due to a shift from coal to gas plants, from less efficient to more efficient plants within the same technology category, or from fossil plants to lower carbon choices during investment and operational choices. With declining carbon intensity, the same amount of power forward contracts can be hedged with a smaller volume of CO_2 allowances. We do not model this effect explicitly, as in recent years the carbon price has been significantly below the price that would motivate a shift, for example, from coal to gas as a baseload generation. Instead we assume a 2% gradual decline in the carbon intensity of production. Reductions of aggregate power consumption are not assumed. Once again, assuming constant carbon intensity, such a reduction would result in a reduction of hedging volumes.

Second, flexibility within the hedging strategy of a power generator can impact on the hedging volume across years. Utilities typically produce with a portfolio of different generation technologies. If a generator sells 20% of production three years ahead, then the generator can either hedge the power production by allocating the production to a coal plant and, thereby, include a carbon hedge, or allocate the production to a non-fossil plant without the need to hedge carbon. In this way, the hedging volume changes with hedging choices, even though the expected power generation mix stays constant.

We estimate the hedging volumes by Western European power generators as a means of quantifying the aggregate CO_2 hedging volume. Since most of the new EU member states use a provision in the EU ETS Directive that allows for continued free allocation of allowances to existing power stations, we do not assume hedging by Eastern European power generators (EU, 2012d). Our hedging volume estimate is based on the power generation mix and power hedging strategies of nine large Western European power generators, EDF, EnBW, Enel, E.ON, GDF Suez, Iberdrola, RWE, Statkraft, and Vattenfall as summarised in Table 2.1.

Table 2.1: Parameters used for calculation of CO_2 hedging volume

Parameter	Value	Sources
Coal power share West EU (GWh)	639,103	EDF (2011), EnBW (2011), Enel (2011), E.ON (2011), Eurostat (2012a), GDF Suez(2011), Iberdrola (2011), RWE(2011), Statkraft (2011), Vattenfall (2011)
Gas power share West EU (GWh)	718,991	
Non-fossil power share West EU (GWh)	1,295,260	
Average weighted power hedging volume (%)	84 one year ahead, 46 two years ahead, 20 three years ahead	E.ON (2011), Eurelectric (2010), Iberdrola interview, RWE(2011), Vattenfall (2011)
Coal CO_2 intensity (tCO_2/MWh)	0.96	IPCC (2006)
Gas CO_2 intensity (tCO_2/MWh)	0.411	

According to this bottom up estimate, power generators in Western Europe hedge on average 20% of the projected generation three years ahead, 46% two years ahead and 84% one year ahead. Power generators follow a common hedging strategy using all technologies to hedge future power sales for all years, in proportion to their expected share in the power production. This gives an aggregate hedging volume of about 1.4 billion tonnes of CO_2 by 2012. Beyond these hedging volumes, power generators reported in the interviews that given their risk management requirements they do not hold significant amounts of allowances. Schopp and Neuhoff (2013) model the hedging strategies by power firms in more detail and find that individual adjustments to expected carbon price increases can in aggregate result in a hedging corridor of 1.1 to 1.7 billion tonnes CO_2.

2.3.2 Industry sector

The industry sector received 569 million free allowances in excess of their requirements to cover emissions between 2008 and 2010 (CITL, 2011; Eurostat, 2012b). Interviewees from the industry sector pointed to some differences in the strategy of firms to the surplus of allowances that they obtained. However, some common themes emerged across firms.

Small industrial emitters are likely to retain the entire volume of surplus allowances to hedge uncertainty in future emissions thereby avoiding the need to buy additional allowances for compliance needs. As they only represent a small fraction of emission and surplus allowances, the main market trends are determined by the larger emitters.

Industrial emitters typically do not have a commodity trading department like power generators. Therefore, they are unlikely to acquire additional allowances beyond the level they received as free allocation. Thus, the estimate of surplus allowance allocation to industry also represents an upper limit to the volume of surplus allowances held by this sector.

In interviews, some firms reported that they directly sell this surplus. In particular, since the financial crisis reduced access to credit and negatively impacted cash flows, the sales of surplus allowances provided an opportunity for quick access to cash. For firms with worsening credit ratings, the opportunity costs of holding allowances has increased with the cost of borrowing money. This has further encouraged sales of unused allowances.

Other firms reported that they retained surplus allowances between 2008 and 2011 to provide for uncertainties in their needs of allowances post 2012. This was encouraged by International Financial Reporting Standards. These standards allow firms to value allowances allocated for free at zero in financial and tax reports. Profits are then reported in the quarter when allowances valued at zero are sold at market prices, or can be attributed to the production process when the zero valued allowances are used as production input. Thus, holding allowances valued at zero enables a smoothing of reported profits (Haupt and Ismer, 2013).

During 2011 the volume of free allowance allocation for the industry sector post 2012 was clarified with the definition of benchmark factors. As the allocation of free allowances to the industry sector in the relevant planning horizon of two to five years turned out to be rather generous, industrial emitters needed to retain fewer surplus allowances to meet emissions not covered by the free allocation. Allowance holding beyond the expected compliance needs have to be interpreted in financial reports as speculative investment and valued at market prices. This might have encouraged industrial emitters to sell surplus allowances during 2011.

In spring 2011, the online accounts of several firms were hacked and allowances were stolen. This had a twin effect. During the first half of 2011, some industrial emitters limited their trading activities whilst they implemented more stringent control procedures, which means that they probably also delayed the sale of surplus allowances. The implementation of more stringent control procedures for a firm may also include a centralised allowance pool at EU level, rather than at installation or national level. Pooling reduces the amount of surplus allowances necessary to cover uncertainties in emission patterns.

To summarise, this variety of factors may have contributed to the sales of surplus allowances and only a fraction of the 569 million allowances was still held by the industry sector by the end of 2011. These developments could have contributed to a decline of the allowance prices from about 15 Euro in the first half of 2011 to around 8 Euro by the end of 2011.

The rapid price drop might have been accelerated by the application of more active risk management procedures by firms. For example, a stop-loss position limits the losses from declining prices of a commodity by requiring a share of the commodity to be sold should the price drop below a pre-defined threshold. This means that part of the value of the commodity is secured for the firm while at the same time, forgoing the opportunity to recover losses with increasing prices. Industrial emitters vary the emphasis that they place on the various factors, and differ in their overall level of sophistication in and their attitude towards commodity trading.

Some interviewees reported that the low carbon price at the end of 2011/early 2012 could have encouraged industrial emitters with strong balance sheets to invest in additional allowances for use in the very long term. We will return to the more speculative investment of this kind when we discuss speculators.

2.3.3 Finance sector

Banks

Investing in commodities, like CO_2 allowances, without hedging the price risk is not the usual business model adopted by banks. Given the historic volatility of the European carbon price, any bank that pursues a speculative investment of this nature has to back the open positions with almost 100% of their own capital as regulated under Basel (EU, 2006b). However, banks prefer to leverage their own capital rather than backing risky investments with their own capital.

It was reported that banks do not pursue significant volumes of speculative investment in EU ETS allowances. Instead banks primarily engage in the arbitrage of allowances. They buy allowances and simultaneously sell forward, future or option contracts, so as to avoid exposure to carbon price risk. The main demand for such financial contracts emerges from the power sector. If power generators use financial contracts as part of the strategy to hedge the carbon price risk of power sales, they do not need to use their own capital to acquire and bank allowances. In this way, the volumes of banked allowances by the financial sector for arbitrage purposes are already accounted for in the analyses of the power and industry sectors. Figure 2.2 depicts growth rates of front year contracts from one year to the next. It shows that CO_2 allowance contracts for 2011 were traded at about 5% discount below 2012 contracts, and contracts for 2012 at about a 7% premium below 2013 contracts. Interviews with experts from the power, industry and finance sectors confirmed that the implied discounts rates are in the order of 5% per year.

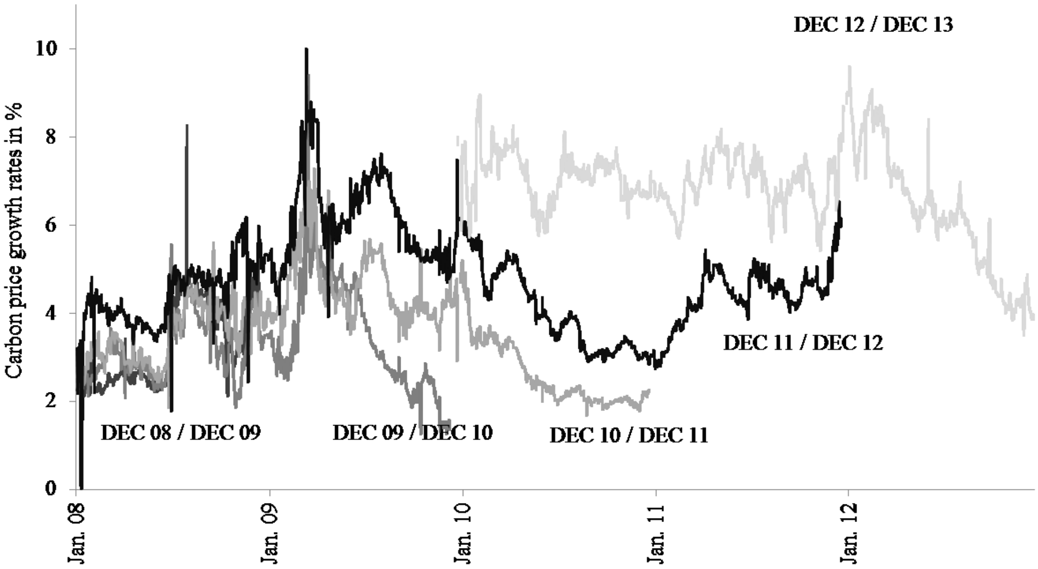

Figure 2.2: Carbon price growth rates
Sources: Based on EEX (2012)

Speculators
Market participants have continuously pursued small-scale speculative investments in CO_2 allowances to arbitrage price changes over short time periods. Some interviewees indicated that industrial emitters with strong balance sheets might avail themselves of the opportunity presented by low carbon prices since the end of 2011 to acquire additional allowances. However, during our interview period (November 2011 – January 2012) no interviewees were able to point to actors who have pursued this type of speculative investment over longer periods.

Financial investors can invest in CO_2 allowances in a portfolio together with other assets that might be negatively correlated with carbon, or pursue investments in allowances as part of a larger portfolio. CO_2 allowances – apart from zero storage costs – have features in common with many other commodities. This means that particular financial contracts on the carbon price can be compared to similar commodity contracts in terms of risk exposure and trading liquidity. It was frequently reported that financial investors would, in principle, be prepared to pursue speculative investments in carbon if annual rates of return exceeded 10-15%.

This is consistent with analyses of hedging pressures in other commodity markets. In the US, market participants report their positions on future contracts on commodities to the Commodity Futures Trading Commission. Econometric analysis of this data shows that future prices include a risk premium on the final realisation of the commodity price. If speculative investors take a long position to accommodate the hedging needs of other market participants then future prices are lower, and if speculative investors take a short position then future prices are higher. Bessembinder (1992) estimates the annual return investors require for bearing the risk at more than 10% for various commodity markets. Wang (2001) performs similar calculations for returns in future markets for the period 1993 to 2000 – using a slightly different metric to determine whether speculators are short or long – and identifies that bearing the risk is rewarded with an annual premium exceeding 5% and in most markets exceeding 10%. Experience from the gold market indicates that the required rate of return may be even higher to compensate for policy risk (Salant and Henderson, 1978).

2.3.4 Contrasting surplus and hedging volumes

Our analysis of the various banking strategies shows that banking volumes by the power and industry sectors are limited by the need of hedging future emissions. Additional surplus allowances can only be banked as speculative investment. This may require new types of investors who are willing to carry the price risk. If these investors require higher rates of return in order to bank allowances, the current price has to decline to a level that allows for such returns in subsequent years.

In Figure 2.3, we show potential aggregate hedging volumes by the power and industry sectors set against our estimate of the cumulated allowance surplus. Between 2008 and 2012, hedging volumes by power generators increased in parallel with the surplus. Retained allowances by industrial emitters were of the order of magnitude to fill the remaining gap. Several factors acted as incentives for industrial emitters to sell some of their surplus allowances during 2011.

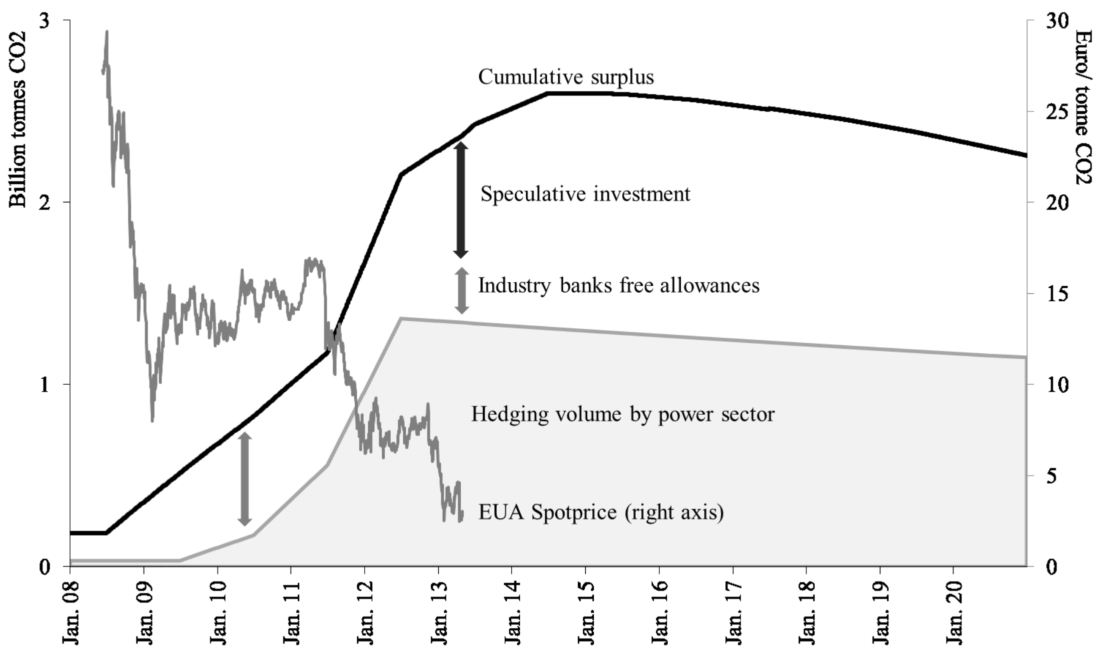

Figure 2.3: Cumulative surplus of CO_2 allowances, hedging volume and carbon price
Sources: Based on data sources listed in Figure 2.1, Figure 2.2 and Table 2.1

As excess supply grew beyond the retained allowances by the industry sector and hedging volumes by the power sector, higher discount rates required by speculative investors may have further depressed current prices. The significant carbon price decline from around 15 to around 3 Euro/ tonne of CO_2 in early 2013 coincided with this development. However, our quantitative analysis based on annual reporting is not sufficiently precise to identify the exact point at which surplus allowances in the market exceeded hedging volumes.

It remains uncertain to what extent the drop in prices can be explained by increasing discount rates compared to reduced price expectations. The increasing surplus of allowances is likely to have impacted on the expected scarcity and, consequently, the allowance price post 2020. This in turn will have contributed to lowering current allowance prices. Several factors need to be considered. With regard to international offset credits, market participants might have not expected that they would be available so quickly, but that the import quotas would not be fully used up even by 2020. This higher availability contributed to lower expectations of scarcity post 2020. The lower current and projected emissions resulting from the recession have had a similar impact. In contrast, the deployment of renewable energy matches the renewable energy targets of the EU Directive at the European average, and cannot be linked to the surplus. A final factor seems to be the EU Energy Efficiency Directive. While the energy and climate package of 2008 formulated indicative energy efficiency targets, there were no legally binding requirements until later. The scale of this potential influence might be reflected by the 10% price drop which followed the draft of the subsequently accepted EU Energy Efficiency Directive issued by the European Commission in June 2011. These factors taken together are unlikely to explain on their own the large carbon price drop.

2.4 Policy implications

The limits on the scale of banking at low discount rates were not considered in the discussions on setting EU ETS caps during the second and third trading period. Emphasis was laid on the value of unlimited banking, reflecting the experience gleaned from the first trading period of the EU ETS, when a regulatory constraint on banking resulted in a drop of carbon prices to zero at the end of 2007 (Alberola et al., 2009).

Higher discount rates can have undesirable outcomes when applied to expectations on future carbon prices. First, if carbon prices increase steeply over time, then cheap mitigation opportunities are initially ignored, while at high carbon prices in future years, additional, expensive mitigation opportunities have to be implemented. This raises the costs of achieving climate goals. Second, firms investing in low-carbon technologies may struggle to convince their boards that future carbon prices will be high given that the current market price is low. For most investors the current carbon price is of relevance because future contracts for CO_2 allowances are only traded actively for a couple of years and therefore carbon prices for 2020 are difficult to derive from markets. Therefore, the current carbon price is used as basis for the strategy and investment choices of firms (Martin et al., 2011). High discount rates, if not considered in evaluations of investment options, can therefore result in reduced and inefficient levels of low carbon investments.

This analysis provides a further argument for the emission cap (including offset quota) to be more closely aligned with the envisaged emission trajectory. In principle this needs to be pursued during the design phase of an emission cap. In response to the low allowance price and recent insights into the functioning of the EU ETS, the European Commission has put forward various policy options that may also contribute to a closer alignment between the emission trajectory and the emission cap (EU, 2012e).

We use the framework of the supply-demand balance of EU ETS allowances to discuss five of these policy options: increasing the 20% emissions reduction target to 30%, permanently setting aside CO_2 allowances, backloading, introducing a reserve price and increasing the linear reduction factor. Figure 2.4 shows their impact on the timing and scale of surplus reduction.

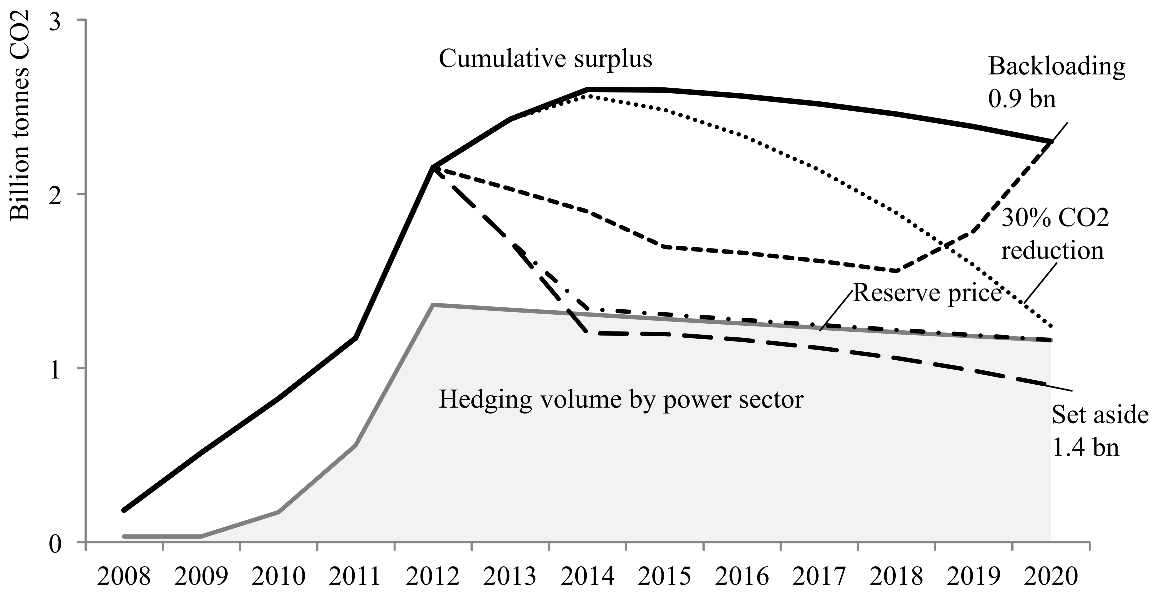

Figure 2.4: Potential impact of policy options on surplus
Sources: Based on data sources listed in Figure 2.1 and Table 2.1

Strengthening the 2020 target to 30%

Strengthening the 2020 emission reduction target from 20% to 30% would gradually reduce the surplus under EU ETS by 1.2 billion tonnes of CO_2. According to our projections the volume of surplus allowances will only be reduced sufficiently by 2019, allowing it to be met by hedging volumes employed by power generators and industrial emitters. The EU ETS Directive envisages that in the case of a target increase to 30%, half of the additional emission reductions requirements will be satisfied with offset credits. If all offsets were allowed to be included, the total surplus would probably only be reduced by 0.6 billion tonnes of $CO_{2,}$ given the significant volume of additional CDM credits.

Strengthening the 2020 target alone may require speculative investors to absorb risk and continued high discounting. To the extent that the tighter target will result in higher expectations for 2020 prices, these will be translated to today's prices, but at a high discount rate.

Set-aside of allowances

The European Parliament's Environmental Committee voted in December 2011 for a set aside of 1.4 billion allowances from EU ETS. In this way the surplus would be reduced so that it could be fully absorbed by the power and industry sectors to hedge future compliance obligations.

Backloading

In November 2012 the European Commission proposed backloading 0.9 billion allowances (EU, 2012c). This proposal sought to reduce the auction volumes in the years 2013 to 2015 and to increase them in the years 2019 to 2020. Backloading reduces the surplus in the short term, but does not change the overall supply of allowances. This means that hedging by power and industry sectors could absorb the surplus in the short term. However, the surplus would exceed hedging volumes at the end of the third trading period.

Reserve price in allowance auctions

In the third trading period, about half of the EU ETS allowances will be auctioned. A reserve price for such auctions could reduce supply until the cumulative surplus matches hedging volumes. Due to the lower discounts applied in hedging, the carbon price could then increase above the reserve price – assuming expectations about future scarcity and prices are sufficiently high. This would require allowances not initially auctioned due to the reserve price not to be subsequently returned to the market. If the reserve price in the allowance auction reduces the cumulative surplus to the extent that it matches the upper end of the hedging volumes, then Figure 2.4 shows that the cumulative surplus over subsequent years will remain at the margin of the hedging volume. Therefore, carbon prices are also likely to remain close to the reserve price and the reserve price would de-facto prescribe a carbon price trajectory.

Reserve prices are often discussed with an alternative objective – that of avoiding the risk of very low carbon prices rather than prescribing a carbon price trajectory. In effect a reserve price could be used to complement a set-aside and ensure that if emissions again declined very drastically, the carbon price would not decline below the reserve price. If a reserve price was implemented only for the fourth trading period – but decided and backed by government commitments in earlier years – it would not only set a minimum price level for the fourth trading period, but would also serve as a reference that 'defined' a minimum prices for the later years of the third trading period of the EU ETS. This might increase the confidence of market participants in the future value of allowances, and might also reduce the return rates required by speculative investors.

2030 target and trajectory

The EU ETS Directive outlines a linear reduction factor of the emissions cap by 1.74% per annum to be continued beyond 2020. Strengthening this target would increase the long term carbon price expectations, as well as the reward for banking allowances. However, the surplus would still exceed hedging volumes during the period 2013-2020, which would require speculative investments and high discount rates for the time being. With high discounting long term scarcity signals are unlikely to have a strong impact on current prices.

The policy options discussed above can also be combined. Withdrawing surplus allowances today (via set-aside or backloading) can reduce the surplus to a level that matches the hedging volumes by the industry and power sectors. Strengthening the cap in turn can increase long term carbon price expectations.

2.5 Conclusion

A central element of emission trading schemes is the ability of market participants to bank allowances that are not used in one period for use in future periods. This creates flexibility for intertemporal optimisation of emission reduction opportunities, and contributes to stability of the carbon price. Regulatory constraints inhibiting the banking of EU ETS allowances between 2005 and 2007, for example, resulted in zero allowance prices as surplus allowances eliminated scarcity prices for much of 2007.

The decline of EU ETS allowance prices from 15 Euro in summer 2011 down to 3 Euro in early 2013 raised new questions about the role of surplus allowance banking. The regulatory framework allows for the banking of allowances beyond 2020. Therefore, the decline of allowance prices could be interpreted as a reflection of the increasing surplus and declining credibility of EU ETS post 2020, thereby depressing expected allowance prices post 2020. This paper identifies a second factor which is essential in understanding the decline of EU ETS allowances, which is the increase in the discount rate applied to expected allowance prices by (new) actors banking surplus allowances.

The analysis is primarily based on the quantification of the surplus of allowances, offsets and contracts on future offsets that has accumulated under the EU ETS as well as on interviews with different groups of market participants, in order to gain an understanding of and a quantification of the different strategies motivating surplus holdings. A surplus has accumulated since 2008, as supply has continuously exceeded emissions. This surplus is primarily linked to the decrease of 0.7 billion tonnes in CO_2 emissions during the economic crisis and the unexpectedly large supply of 1.7 billion international project credits. The power and industry sectors primarily acquire allowances to hedge the input costs for future production. In these cases banks can offer forward contracts for CO_2 allowances at premiums of the order of 5% per year, reflecting the opportunity costs of capital needed to acquire hold the physical allowances. Once the volume needed by the power and industry sectors for hedging is satisfied, the carbon price may decline to a level that becomes sufficiently attractive for speculative investors. Speculative investors may buy allowances like other commodities, but only if the expected returns compensate for the risks associated with the future carbon price development. Our results show that the decline of the CO_2 allowance price coincides with the time when the surplus of allowances actually exceeded the hedging volumes by the power and industry sectors. It is therefore consistent with the argument that the discounting of future allowance prices has increased due to the increased surplus.

The analysis shows that intertemporal arbitrage through banking has its constraints. If excess supply at a point in time grows too large, in the short run prices may be further depressed as carbon price expectations are highly discounted. This indicates that supply needs to approximate to anticipated demand and use. The quantitative framework for the holding of surplus allowances can be used to evaluate policy design options contributing to such an alignment.

2.6 Appendix

Table A: Demand and supply balance of the EU ETS (in billion tonnes CO_2)

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
EUA Allocation	2.08	2.08	2.08	2.08	2.30	2.25	2.21	2.17	2.14	2.10	2.06	2.02	1.99
Reference scenario	2.12	1.88	1.94	1.91	2.15	2.23	2.21	2.19	2.16	2.14	2.12	2.10	2.09
CPI scenario	2.12	1.88	1.94	1.90	2.14	2.21	2.19	2.16	2.13	2.11	2.08	2.06	2.04
High RES scenario	2.12	1.88	1.94	1.89	2.12	2.18	2.15	2.11	2.07	2.04	2.01	1.97	1.94
NER (300)	-	-	-	-	0.20	0.26	0.23	0.19	0.15	0.11	0.08	0.04	-
NER Phase II	- 0.09	- 0.17	- 0.26	- 0.35	-	-	-	-	-	-	-	-	-
Early auctioning	-	-	-	-	0.12	0.06	-	-	-	-	-	-	-
CER and ERU	0.31	0.52	0.78	1.03	1.18	1.42	1.66	1.68	1.68	1.68	1.68	1.68	1.68
Surplus cum.	0.18	0.51	0.83	1.17	2.15	2.43	2.60	2.60	2.56	2.52	2.46	2.39	2.30
Hedging cum.	0.03	0.03	0.17	0.56	1.36	1.34	1.31	1.28	1.26	1.23	1.21	1.18	1.16

Note: Cap and emissions include aviation and new sectors. Cumulative surplus is based on Current Policy Initiative (CPI) emissions scenario. Based on data sources listed in Figure 2.1 and Table 2.1.

3. Can banking CO_2 allowances ensure intertemporal efficiency?

Anne Schopp and Karsten Neuhoff

The banking of CO_2 allowances in cap-and-trade schemes allows surplus allowances to be transferred to future years. Intertemporal efficiency is ensured, providing market participants bank the allowances in the expectation of modest price increases. However, as the surplus of allowances in the European Emission Trading Scheme has accumulated, market participants are reporting that they only hold surplus CO_2 allowances at modest discount rates to the extent that they need these allowances in order to hedge future CO_2 exposure. Once their hedging demand is exhausted, the remaining surplus needs to be banked as speculative investment. (New) market participants may speculate if high discount rates compensate them for the risk of uncertain carbon price developments. However, highly discounted carbon price expectations can delay low carbon investment and thus jeopardize intertemporal efficiency. This raises the question as to what volume of surplus allowances can be hedged in order to ensure intertemporal efficiency. In an attempt to answer this question we model hedging demand in the power sector as a function of the carbon price structure and risk management strategies reported by power firms in interviews. This partial equilibrium analysis is then integrated into a two period CO_2 supply and demand model with emitting firms, hedging by power firms and banking of allowances by speculative investors. The model demonstrates that hedging flexibility could balance a CO_2 allowance surplus in the range of 1.1 to 1.7 billion by the end of 2012 at discount rates of carbon price expectations between 0 to 10%; and that discount rates increase with increasing surplus levels.

Keywords: Banking; Discount rates; Emissions trading schemes; Power hedging

3.1 Introduction

In emission trading schemes, CO_2 allowance caps are fixed several years in advance and do not respond to variations in demand. At the end of the first European Emission Trading System (EU ETS) period, supply exceeded demand. As surplus CO_2 allowances could not be banked for use in future periods, prices dropped to zero (Chevallier, 2011). In the second trading period a large surplus of more than 2 billion tonnes of CO_2 has accumulated and is expected to grow (Neuhoff et al., 2012). However, the carbon price in the EU ETS did not drop to zero at the end of the second trading period because market participants were allowed to bank allowances for use in future periods. In other words, banking can help stabilise carbon prices and contribute to intertemporal efficiency.

These surplus allowances can be banked by market participants to hedge future production or as a speculative investment.[1] Interviews with European market participants in 2011/ 2012 showed that most hedgers are power firms (Neuhoff et al., 2012). They hold allowances to hedge the cost of CO_2 allowances when they sell power several years ahead. The hedging volumes can vary over time. On the one hand, the CO_2 intensity of power generation changes with the deployment of renewables as well as with fuel and carbon prices. As a result the volume of allowances required to hedge future power generation also changes. On the other hand, power firms can choose to adjust the volume of power they sell on forward contracts, and can decide to use coal, gas, or low carbon generation to back forward sales. This can alter the volume of CO_2 allowances required to hedge input fuels and, consequently, CO_2 prices.

A peculiar feature of the allowance market is that CO_2 allowances can be banked at zero cost. This means that banks can offer forward contracts for CO_2 allowances at the price at which they acquire allowances in the spot market, times the opportunity costs of capital over the duration of the forward contract. This creates an upper bound on the forward price. In the second trading period future contract prices increased on average at 5% per year (historic values) over the spot price (EEX, 2012).

Obviously, if market participants expect future allowance prices to exceed the price at which forward contracts are traded, they could decide to acquire additional allowances as a speculative investment. This would increase scarcity and therefore current prices, while reducing scarcity and prices in the future until the forward contracts actually reflect the expected prices. In practice, there are limits to this intertemporal arbitrage. According to interviews with market participants of the EU ETS as well as experience in other commodity markets speculative investors may acquire allowances if they expect an annual rate of return exceeding 10-15% (Neuhoff et al., 2012). Thus, speculative investors would not provide for intertemporal arbitrage, even if all market participants expect the carbon price to increase at, say, 8% per year. Therefore, in this situation the expected price for allowances can differ in equilibrium from the price of forward contracts.

[1] Arbitrageurs also bank CO_2 allowances. Their demand does not add to the banking demand from hedgers and speculators, as their counter parties are typically hedgers, e.g. power firms.

This motivates the question examined in this paper: How does the hedging volume of power firms evolve in response to deviations between the price at which forward contracts are traded and the expected price? The flexibility of the hedging volume (given fixed supply of allowances) determines the intertemporal flexibility of emission trading schemes and the stability of carbon prices in such schemes.

To address this question, we model the flexibility of the hedging volume with CO_2 allowances by power firms, based on corporate risk management procedures identified in 13 semi-structured interviews. Power firms reported that the volume of power sold forward as well as the allocation to different generation assets is adjusted according to deviations of forward prices from firms' expectations. If a power firm expects the CO_2 price to significantly exceed the price at which forward contracts are traded, then it may increase the total contracted volumes of power forward sale and also increase the contracted volumes of carbon intensive (fossil) generation assets (and the associated CO_2 allowances) used to hedge price changes. This allows the firm to profit from the expected increase in carbon prices over time. According to our estimates such individual adjustments could result in an overall CO_2 hedging volume in the range of 1.1 to 1.7 billion allowances by the end of 2012 at discount rates of carbon price expectations between 0 to 10% (Figure 3.1).

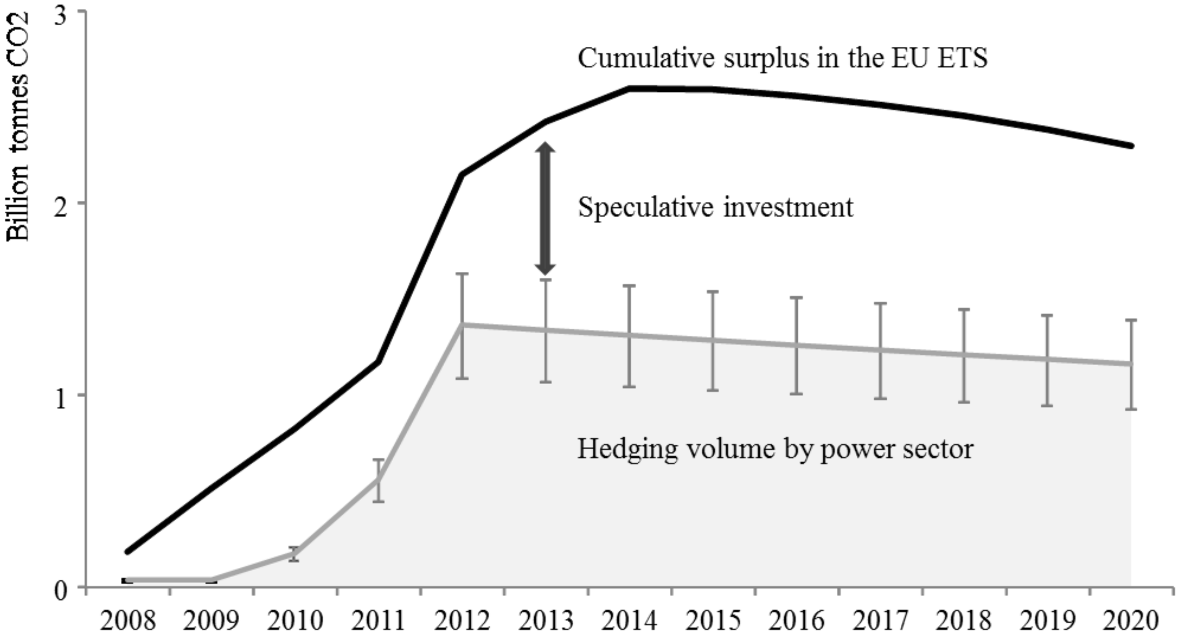

Figure 3.1: Surplus of CO_2 allowances and hedging volume

Sources: Based on Neuhoff et al. (2012) and data sources listed in Table 3.2

As the cumulative surplus in the EU ETS exceeds the hedging volume by power firms, we further consider the impact of CO_2 banking by speculative investors.[2] Neuhoff et al. (2012)

[2] For simplicity, the retaining of free allowances by the industry sector is not included. For an extensive discussion on banking strategies by industrial emitters see Neuhoff et al. (2012).

argue that speculative investors may have an incentive to bank CO_2 allowances if they expect large price increases in the forthcoming years, since they require high rates of return. We model the equilibrium in the CO_2 market using a simplified two-period framework with emitting firms, hedgers and speculators. We demonstrate that as the surplus increases, the discrepancy between forward prices and price expectations widens gradually and the discount rates applied to carbon price expectations increase.

The paper is structured as follows: Section 2 reviews the relevant literature on banking. Section 3 models the CO_2 allowances volumes European power generators use to hedge forward power sale. Section 4 integrates CO_2 hedging into a market equilibrium model with emitting firms and CO_2 banking by speculative investors in order to illustrate the carbon price dynamics given different types of actors who bank surplus allowances. Section 5 draws conclusions.

3.2 Literature

Both theoretical and empirical analysis demonstrates the efficiency of banking in emissions trading. In theory, the intertemporal flexibility of banking can reduce overall mitigation cost, as firms are allowed to hold CO_2 allowances for future use and invest in emissions-reducing technologies, thereby distributing their emissions over time (Rubin, 1996). Firms have an incentive to bank CO_2 allowances if they expect future carbon prices to increase. With banking prices are expected to follow Hotelling's rule and increase with the rate of interest (Cronshaw and Kruse, 1996; Kling and Rubin, 1997).

In line with this theory, Ellerman et al. (2007) provide empirical evidence for the SO_2 US Acid Rain programme. They show that firms banked an efficient volume that allowed for reducing the overall abatement cost of the scheme. To evaluate banking of SO_2 allowances the authors assume constant discount rates of 3-5%. Policy impact assessment of the EU ETS assumed gradually increasing prices and thus implicitly assumed a similar level of discount rates: price projections for 2020 prices of more than 30 Euro/ tonne of CO_2 relative to prices of 20 Euro/ tonne of CO_2 in 2008 imply discount rates of more than 3% (EU, 2008b; DECC, 2009).

This assumption of unlimited banking at constant low discount rates in economic models may not hold in the EU ETS, where a large surplus has accumulated. Experience from other commodity markets suggests that market participants only bear the risk of holding a commodity if they are rewarded with a risk premium, which can exceed 10% per year (Bessembinder, 1992; Wang, 2001). Bailey (2005) groups motives for trading future contracts into hedging, arbitrage and speculation. According to Neuhoff et al. (2012) the EU ETS surplus is mainly banked by hedgers, e.g. power firms, who hold CO_2 allowances in order to reduce risk exposure of future production to price changes. Financial actors also acquire CO_2 allowances. Their demand does not add to the banking demand, if they merely buy allowances and sell forward contracts or other contract types of the corresponding volume. In effect, banks sell e.g. forward contracts that are used by power firms to hedge future power sales. This reduces the need for power firms to hold allowances on their balance sheet, but does not increase the net demand for allowances. Speculators can buy CO_2 allowances with the expectation that prices will increase more than reflected in the market. They bear the risk that their expectation may not be realized and, consequently, require high rates of return.

Theoretical arguments suggest that investors acquire CO_2 allowances as part of an asset portfolio including equity, bonds or alternative investments such as power generation technologies. Diversifying a portfolio would reduce their risk exposure if the assets' returns are not perfectly correlated (Markowitz, 1952). Daskalaskis et al. (2009) assess this effect and find that EUA futures are negatively correlated with equity market returns. Chevallier (2009) observe a limited correlation between CO_2 allowances prices and the price of equity and bond assets. Empirical evidence by Gronwald et al. (2011) suggests however a significant positive dependence between EUA future and energy future returns as well as equity spot returns.

To date, the intertemporal role of banking in the case of large surpluses, as observed in the EU ETS, is not addressed. This paper aims to contribute to the literature by accounting explicitly for different motives to bank CO_2 allowances, i.e. hedging and speculation. In so doing, we demonstrate carbon price dynamics given different types of banking and evaluate policy options to back-load or set-aside surplus allowances.

3.3 Hedging with CO_2 allowances by power firms

We build a model that allows for a quantification of the hedging volume of CO_2 allowances. To inform the model, we conducted interviews with power firms in 2012. Following purposive sampling we contacted the main power firms in Western Europe, since, unlike most power firms in Eastern Europe, they do not receive free CO_2 allowances from 2013 onwards. Hedging experts from 13 power firms responded, accounting for 56% of European power production (MVV Energie, 2010; Badenova, 2011; DONG Energy, 2011; EDF, 2011; EnBW, 2011; Enel, 2011; Enercity, 2011; GDF Suez, 2011; Iberdrola, 2011; RWE, 2011; Stadtwerke München, 2011; Statkraft, 2011; Vattenfall, 2011). The interviews covered three aspects:

- the main factors that determine hedging with CO_2 allowances,
- the metrics to formulate the hedging schedule, and
- thresholds to deviate from the hedging schedule.

3.3.1 Two-period model of CO_2 hedging by power firms

In the interviews, power firms reported that they sell power several years ahead of production in order to reduce their exposure to price risks and profit volatility from power production. To lock in profits from the power sold in advance, firms also acquire the input factors, namely coal, gas, and CO_2 allowances or contracts that secure the price for these inputs.

We use a two-period model to illustrate the mechanics of the partial equilibrium model, and subsequently present results calibrated to the empirical contracting strategy, therefore allowing for up to four years of forward contracting.

In period one of the model, the years prior to production, the firm sells part of the power E that will be produced in period two on forward contracts e_1 and, at the same time, acquires part of the coal C and gas G (and the associated CO_2 allowances) used for power production on forward contracts c_1, g_1. In period two, the year of production, the firm contracts the remaining power to match projected generation $E - e_1$ and acquires the required input factors or contracts that secure the input prices. The model focuses on the forward contracting strategy, as this has the largest impact on total hedging demand.

In the interviews, it was also reported that the volume and the period for which power is sold forward is a corporate strategy decision. In the model therefore the firm formulates a hedging schedule, based on its expected generation portfolio: γ_1% of power is sold in period one and γ_2% is sold in period two. Several power firms reported that they prefer to hedge uniformly across the portfolio of their generation assets rather than hedging with a strong emphasis on one specific generation technology. Hence, the hedging schedule specifies that in parallel the firm buys in proportion to its generation portfolio γ_1% of coal C and gas G in period one and γ_2% in period two. To reflect the preference to hedge across the portfolio, deviations from this proportional hedging schedule are included with a quadratic penalty term, where α can be interpreted as the internal transaction cost.

Hedging schedule:

$$\alpha((\gamma_1\, C - c_1)^2 + (\gamma_1\, G - g_1)^2). \tag{1}$$

However, power firms reported that they can deviate from their hedging schedule, if it is attractive for them. In the model, power firms can adjust the hedging volume, when firms' expectations about future energy and carbon prices differ from forward contract prices in the market. For example, if the forward price at which power can be sold forward in year one p_1^e deviates from the power price that the firm expects to materialise in period two $E(p_2^e)$ then it can increase the volume of power sold in period one e_1 and decrease the power sold in period two e_2. Therefore, in period one the firm considers the revenues from forward sales in period one and the remaining short-term sales in year two.

Similarly, if the carbon price $E(p_2^{CO2})$ is expected to increase above the price at which forward contracts are traded in period one p_1^{CO2}, power firms have an incentive to prioritise hedging future power sales with generation by carbon intensive assets in period one, e.g. coal c_1 (rather than gas g_1). To avoid risk exposure on the input factors, the firm chooses the volume of allowances bought on forward contracts to match the power production from coal and gas sold on forward contracts. The required volume of CO_2 allowances to cover the emissions depends on the carbon intensity of the coal plants i_{CO2}^{g} and of the gas plants i_{CO2}^{g}. Hence, if more coal is used to hedge future power sales in period one, the hedging demand for CO_2 increases in period one (and decreases in period two).

Hedging flexibility:

$$e_1\, p_1^e + (E - e_1)\, E(p_2^e) - \left[c_1 \left(\frac{p_1^c}{f^c} + i_{CO2}^c\, p_1^{CO2}\right) + (C - c_1)\left(\frac{E(p_2^c)}{f^c} + i_{CO2}^c E(p_2^{CO2})\right)\right] - \left[g_1 \left(\frac{p_1^g}{f^g} + i_{CO2}^g\, p_1^{CO2}\right) + (G - g_1)\left(\frac{E(p_2^g)}{f^g} + i_{CO2}^g\, E(p_2^{CO2})\right)\right] \quad (2)$$

where f^c represents the thermal efficiency of the coal-fired power plants and f^g the thermal efficiency of the gas plants.

In the interviews, it was also reported that open positions in power sales are avoided. This implies that the power forward sale in period one must be matched by forward contracts where coal and gas are required to produce the power $e_1 = c_1 + g_1$.

The power firm chooses the contract volume of coal and gas in year one, so as to maximise its objective function based on the two factors, namely hedging schedule and hedging flexibility, (combining equations (1) to (2) and substituting $e_1$by $c_1 + g_1$):

$$\max_{c_1, g_1} - (c_1 + g_1)(E(p_2^e) - p_1^e) + (C + G)\, E(p_2^e) + c_1\left(\frac{E(p_2^c) - p_1^c}{f^c} + i_{CO2}^c(E(p_2^{CO2}) - p_1^{CO2})\right) - C\left(\frac{E(p_2^c)}{f^c} + i_{CO2}^c\, E(p_2^{CO2})\right) + g_1\left(\frac{E(p_2^g) - p_1^g}{f^g} + i_{CO2}^g(E(p_2^{CO2}) - p_1^{CO2})\right) - G\left(\frac{E(p_2^g)}{f^g} + i_{CO2}^g\, E(p_2^{CO2})\right) - \alpha((\gamma_1\, C - c_1)^2 + (\gamma_1\, G - g_1)^2). \quad (3)$$

The objective function is subject to the constraint that the firm does not hedge more than it can generate:

$$C - c_1 \geq 0, \qquad G - g_1 \geq 0, \qquad c_1,\, g_1 \geq 0. \quad (4)$$

The corresponding first order conditions of the Lagrangian L are the following:

$$\frac{\partial L}{\partial c_1} = -(E(p_2^e) - p_1^e) + \frac{E(p_2^c) - p_1^c}{f^c} + i_{CO2}^c(E(p_2^{CO2}) - p_1^{CO2}) + 2\alpha\,(\gamma_1\, C - c_1) - \lambda_1 = 0, \quad (5)$$

$$\frac{\partial L}{\partial g_1} = -(E(p_2^e) - p_1^e) + \frac{E(p_2^g) - p_1^g}{f^g} + i_{CO2}^g(E(p_2^{CO2}) - p_1^{CO2}) + 2\alpha\,(\gamma_1\, G - g_1) - \lambda_2 = 0, \quad (6)$$

$$\frac{\partial L}{\partial \lambda_1} = C - c_1 \geq 0, \quad (7)$$

$$\frac{\partial L}{\partial \lambda_2} = G - g_1 \geq 0, \quad (8)$$

$$c_1,\, g_1 \geq 0. \quad (9)$$

In our subsequent analysis we focus on the demand and prices for forward contracts for CO_2 allowances and assume that expectations for prices of the remaining commodities, namely power, coal and gas match forward contracts prices. With $\lambda_1 = 0$, $\lambda_2 = 0$ and $C - c_1 \geq 0$, $G - g_1 \geq 0$ (internal solution) equations (5) and (6) can be rewritten as:

$$c_1 = \frac{1}{2\,\alpha}\, i^c_{CO2}(E(p_2^{CO2}) - p_1^{CO2}) + \gamma_1\, C, \tag{10}$$

$$g_1 = \frac{1}{2\,\alpha}\, i^g_{CO2}(E(p_2^{CO2}) - p_1^{CO2}) + \gamma_1\, G. \tag{11}$$

From the optimal coal and gas volumes contracted in period one (10, 11) follows the hedging volume of CO_2 allowances acquired in period one h_1 to hedge production in period two:

$$\begin{aligned} h_1 &= c_1\ i^c_{CO2} + g_1\ i^g_{CO2} \\ &= \left(\frac{1}{2\,\alpha}\, i^c_{CO2}(E(p_2^{CO2}) - p_1^{CO2}) + \gamma_1\, C\right) i^c_{CO2} + \left(\frac{1}{2\,\alpha}\, i^g_{CO2}(E(p_2^{CO2}) - p_1^{CO2}) + \gamma_1\, G\right) i^g_{CO2}. \end{aligned} \tag{12}$$

Equation (12) reduces to the hedging schedule $(\gamma_1\, C\, i^c_{CO2} + \gamma_1\, G\, i^g_{CO2})$, if expectations of future carbon prices match forward contracts for CO_2 allowances. If expectations are higher $(E(p_2^{CO2}) = (1 + \delta^e_{CO2})\, p_1^{CO2} > p_1^{CO2})$, power firms deviate from their hedging schedule and contract greater volumes of coal and gas. In this case, power firms acquire more CO_2 allowances today and less later on; leading to an increase in the hedging demand for CO_2 allowances in the short-term.

3.3.2 Parameterisation of CO_2 hedging volume

To quantify the CO_2 hedging demand by the power sector, we extend the model to allow for forward contracting up to four years prior to production $(t{:}\ 1,2,3,4)$ and to three generation technologies: coal C, gas G and non-fossils R (see Appendix A). As with the two-period model, it is attractive for power firms to deviate from their hedging schedule when their expectations of future carbon prices differ from forward contract prices.

To quantify, bottom-up, the hedging volume in the power sector, we use the hedging schedule of Western European power firms weighted by their power share. Data on the actual volume of CO_2 allowances that firms hold for hedging or speculative purposes is released with a five year delay (EUTL), whilst data on the volume of financial contracts used for hedging are not available. We therefore derive the hedging schedules from their energy contracting volumes. Three power firms disclosed their hedging schedule in their 2010 annual reports (E.ON, 2011; RWE, 2011; Vattenfall, 2011). For the remaining firms, we rely on a survey conducted by Eurelectric (2010). Table 3.1 shows that the hedging need for CO_2 allowances has increased since 2010 because many power firms acquire their CO_2 allowances at auction and, since 2013, no longer receive them free of charge. The resulting schedule to hedge power is: 20% of power production three years ahead, 46% two years ahead, 84% one year ahead of production, i.e. 150% of the annual emissions by the end of 2012. This calculation excludes hedging demand from Eastern European utilities since most of the new EU member states allow for continued free allocation of allowances to existing power plants in the third trading period, thus largely avoiding the need for power firms to acquire allowances for hedging purposes (EU, 2012d). Official reports and interview results led us to assume that in Spain utilities only hedge one year ahead.

Table 3.1: Average hedging schedule in %

Year i / Year j	2010	2011	2012
2013	20	26	38
2014	0	20	26
2015	0	0	20
% of power hedged in year i for years j	20	46	84

The parameters used to quantify the hedging volume in the power sector are summarised in Table 3.2

Table 3.2: Parameter assumptions of CO_2 hedging model

Parameter	Unit	Value	Source
p_1^e	Euro/ MWh	51.40	EEX (2012), Ø price Jan-May 2012
p_1^c	Euro/ MWh	12.10	
p_1^g	Euro/ MWh	26.90	
C	GWh	639,103	E.ON (2011), EDF(2011) EnBW (2011), Enel (2011), Eurostat (2012a), GDF Suez (2011), Iberdrola (2011), RWE (2011), Statkraft (2011), Vattenfall (2011)
G	GWh	718,991	
R	GWh	1,295,260	
γ_1	%	20	E.ON (2011), Eurelectric (2010), Iberdrola interview, RWE (2011), Vattenfall (2011)
γ_2	%	46	
γ_3	%	84	
i_{CO2}^c	t CO_2/ MWh	0.96	IPCC (2006)
i_{CO2}^g	t CO_2/ MWh	0.41	
f^c	%	40.80	IEA et al. (2010)
f^g	%	55.10	

To calibrate the penalty function for deviations from the hedging schedule α, we use information from the interviews. Some power firms reported that it requires a difference of one to four Euro/tonne of CO_2 between forward contract prices and the firm's or analyst's carbon price expectation to trigger a deviation from the hedging schedule. Furthermore, it was

reported that such deviations are in the order of 10%. We therefore set the internal transaction cost parameter α such that if firms expect carbon prices to be one Euro higher than the price at which carbon forward contracts are traded, they increase their hedging volume by 10%.
We also consider how the hedging volume changes when carbon prices are lower or α is set at a higher value, so that firms require a higher price incentive to deviate from their hedging schedule.

Table 3.3: Sensitivity analysis

Parameter	**Unit**	Base case	2012 CO_2 price	Lower sensitivity
α_1	Euro/ GWh	0.00000845 →1 Euro/ t CO_2, Δ10% hedging	0.00000845	0.0000171 →2 Euro/ t CO_2, Δ10% hedging
p_1^{CO2}	Euro/ t CO_2	20	7.5 Ø Jan-May2012	20

3.3.3 Quantification of CO_2 hedging volume

The hedging model is formulated as a mixed complementarity problem and programmed in GAMS (see Appendix B). We use it to calculate the hedging volume of the power sector for different carbon price expectations (Figure 3.2).

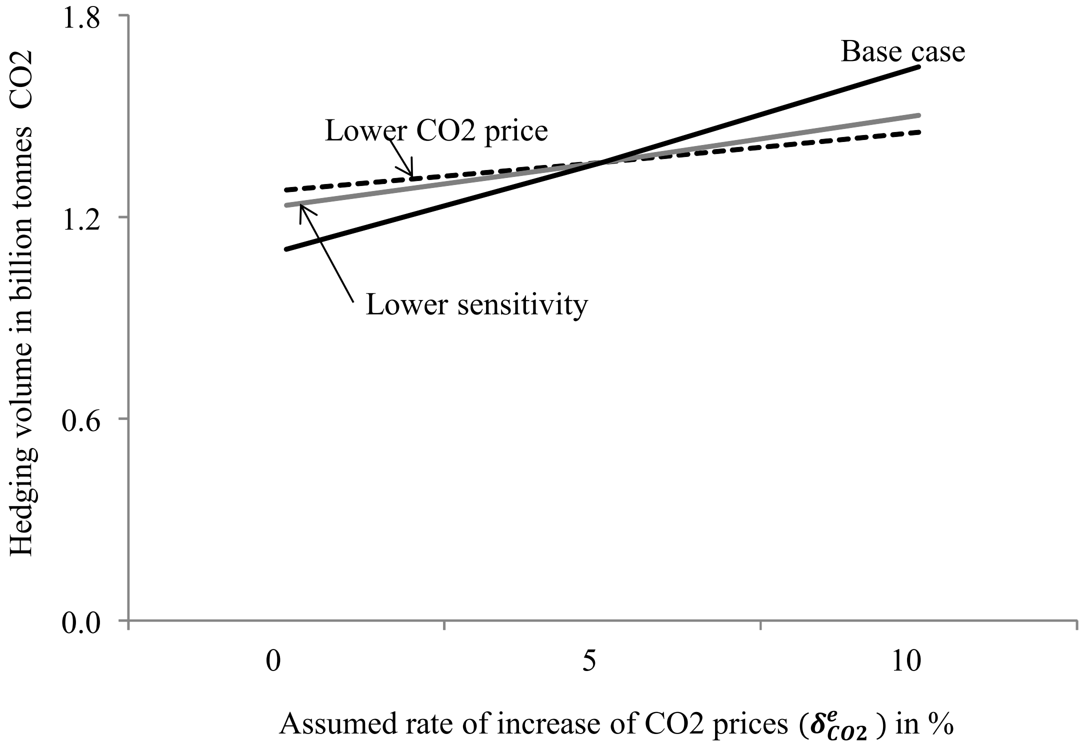

Figure 3.2: Flexibility in CO_2 hedging volume for different expected discount rates

If power firms expect that carbon prices increase with the opportunity cost of capital for banks selling forward contracts, $\delta_{CO2}^{m} = \delta_{CO2}^{e} = 5\%$, then they follow the hedging schedule, set at 20% three years ahead, 46% two years ahead and 84% one year ahead of production. This corresponds to a hedging volume of 1.4 billion tonnes of CO_2 by the end of 2012 or 150% of the annual emissions.

If market participants expect carbon prices to be flatter than reflected in forward contract prices, e.g. $\delta_{CO2}^{e} = 0\%$, $\delta_{CO2}^{m} = 5\%$, the hedging volume will decrease below the hedging schedule. Equally, the hedging volume will increase above the hedging schedule, if power firms expect that carbon prices will increase faster than reflected in forward contract prices, $\delta_{CO2}^{e} = 10\%$. The CO_2 hedging volume ranges from 1.1 to 1.7 billion tonnes of CO_2 by the end of 2012, assuming a current forward price of 20 Euro per tonne of CO_2 and expected carbon price increases of 0-10% (black line). This demonstrates that CO_2 hedging can potentially provide some flexibility to the supply-demand-balance of the EU ETS.

However, carbon prices have dropped in 2011 and amounted in 2012 on average to 7-7.5 Euro. Assuming a carbon price of 7.5 Euro per tonne of CO_2, the hedging volume ranges from CO_2 volume 1.3 to 1.5 billion tonnes (black dotted line). Hence, with lower CO_2 prices, the flexibility of the power sector to adjust the hedging volume decreases.

To examine the sensitivity of the results, we also consider a higher level of α. This means firms are less sensitive, as they need to expect that prices will be at 2 Euro above forward prices in order for them to increase their hedging volume by 10%. In this case the hedging volume ranges from 1.2 to 1.5 billion tonnes (grey solid line). In general, the higher the firm's internal transaction costs in responding to arbitrage opportunities are, the lower the adjustment of the hedging volume to price expectations will be.

3.4 CO_2 market equilibrium with emitters, hedgers and speculators

The supply of allowances in the EU ETS exceeds the demand by emitters to meet current compliance obligations and the hedging volume by power firms to meet future compliance obligations. Additional surplus allowances need to be banked as speculative investment. Figure 3.3 illustrates the implications of these two types of banking, (i) banking to meet future compliance, (ii) banking as speculative investment, for carbon price developments.

Hedging by power firms can be satisfied by banks that provide forward contracts. If banks back these contracts with physical allowances they do not carry the price risk and thus can offer such contracts at the cost of capital. This behaviour is reflected in the implied discount rate by comparing forward contract prices to current spot prices. In the second trading period future contracts prices were traded on average at 5% discount above spot prices (EEX, 2012).

Allowances have many features common to commodities like metals or fuels (except zero storage cost). This suggests that market participants have similar return requirements for banking EU ETS allowances as speculative investment as they have for investing in other commodities, often in the order of 10-15%. If the carbon price has to appreciate by 10% (or more) year-on-year to attract investors in banking CO_2 allowances, then long term price expectations are discounted higher and current prices are lower.

The trajectory of carbon prices as implied by banking as speculative investment seems initially inconsistent with the prices at which carbon is traded for the next 3-4 years. The discrepancy can be explained by the fact that the prices of carbon traded for the next few years result from carbon arbitrage with allowances traded in spot markets. These prices are therefore a projection of the current price, rather than derived from the expectation of the 2020 prices. It also needs to be noted that ensuring sufficiently high price expectation is equally important, i.e. a decline in price expectation shifts the z-curve down and thus also results in a decline in current prices (given constant discount rates).

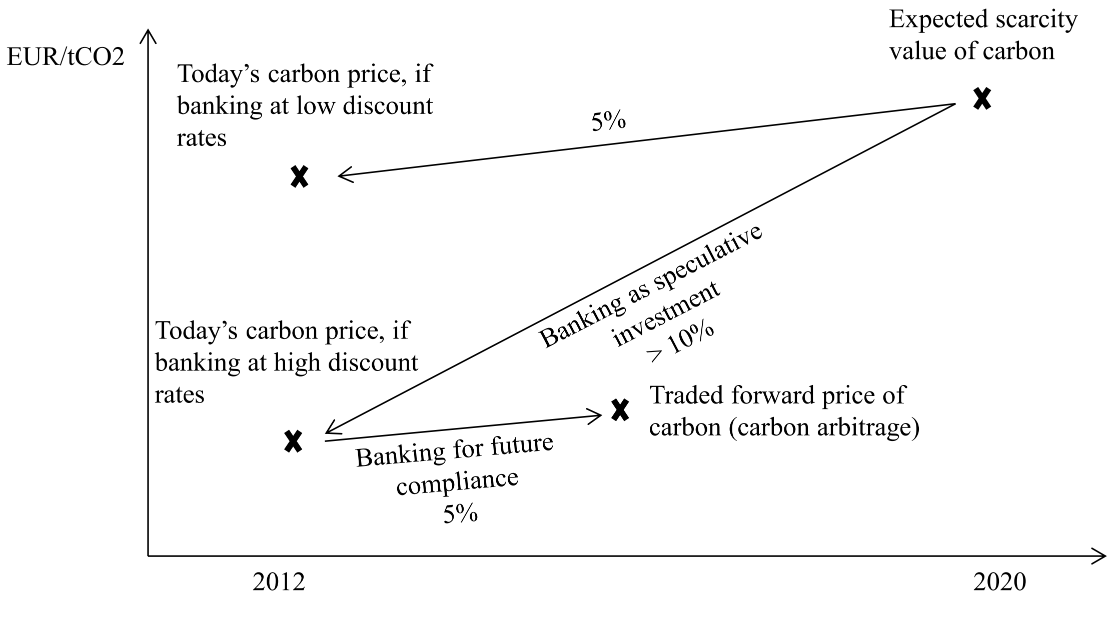

Figure 3.3: Conceptual framework of banking types and discount rates

We model the effect of banking at different discount rates for a two-period framework with CO_2 price dependent emitting firms, hedgers and speculators.

3.4.1 Two-period model of CO_2 emitters, hedgers and speculators

We assume that in each period the allocation of allowances is fixed and that the emissions decrease with an increase in allowance prices p_t^{CO2} according to the emission responsiveness parameter β_t. As a result the net surplus $Q_t^{surplus}$ of allowances in period t increases with increasing prices:

$$Q_t^{surplus} = \theta_t + \beta_t \, p_t^{CO2} \tag{13}$$

The unused allowances from period one $Q_t^{surplus}$ can be banked for usage in period two. Demand for these allowances derives from hedgers Q^h and speculators Q^s .
Hedgers acquire CO_2 allowances to secure the prices of future production as formulated in equation (14). As in the four period model, we assume that banks offer forward contracts at forward market prices that increase at a fixed rate δ_{CO2}^m between the periods of years n. Hedgers can acquire these forward contracts and thus avoid using cash. If they expect that prices $E(p_2^{CO2})$ increase at a higher rate than reflected in the market $p_1^{CO2}(1+\delta_{CO2}^m)^n$, they hedge more in period one and less in period two and vice versa:

$$Q_1^h = \left(\frac{1}{2\,\alpha}\, i_{CO2}^c \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2}\right) + \gamma\, C\right) i_{CO2}^c + \left(\frac{1}{2\,\alpha}\, i_{CO2}^g \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2}\right) + \gamma\, G\right) i_{CO2}^g \tag{14}$$

Speculators do hold CO_2 allowances not to hedge future production, but to make profit by betting that the price will develop in a certain way. They have an incentive to acquire CO_2 allowances if they expect carbon prices to increase at the discount rate exceeding their return requirements, $\delta_{CO2}^e \geq \delta_{CO2}^s$. The discount rate refers to the growth rate between the forward contract price in period one and the expected carbon price in period two, $\delta_{CO2}^e = \sqrt[n]{E(p_2^{CO2})/p_1^{CO2}} - 1$. Thus, the speculative demand can be formulated as a maximum function:

$$Q_1^s = \max(\varphi\,(\delta_{CO2}^e - \delta_{CO2}^s), 0) \tag{15}$$

The speculative demand increases with the expected carbon price in period two and decreases with the forward contract price in period one. The increase in the speculative demand depends also on the factor φ. For φ towards infinity a fixed large volume of speculative demand is available at return rate δ_{CO2}^s.

Equations (14) and (15) form the overall demand in period one. Equalising demand to the cumulative market surplus yields the equilibrium price. The market equilibrium in period one is:

$$Q_1^{surplus} - Q_1^h - Q_1^s = 0 \tag{16}$$

An unexpected decrease in emissions, for example, triggers a price reduction in period one. This in turn triggers a combination of an emission increase in period one and an increase in banking and hedging from period one to period two.

In period two, the surplus and the volume of allowances transferred from period one through banking and hedging needs to be in balance. In the two-period model, market participants cannot bank allowances for use in later periods:

$$Q_2^{surplus} + Q_1^h + Q_1^s = 0 \tag{17}$$

To solve the model we consider two cases: equilibrium with and without demand from speculative investors.

Equilibrium in case of no speculative demand

In case one, speculators expect that the carbon price will increase at a rate below their return requirements, $\delta_{CO2}^{e} < \delta_{CO2}^{s}$, and thus speculative demand is zero. Solving the market equilibrium for the price in period one yields (see Appendix C):

$$p_1^{CO2} = \frac{-\theta_1 + \gamma\left(C\, i_{CO2}^{c} + G\, i_{CO2}^{g}\right)}{\beta_1 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha}} + \frac{\left(-\theta_2\,\beta_1 - (\theta_1+\theta_2)\frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha} - \gamma\,\beta_1\left(C\, i_{CO2}^{c} + G\, i_{CO2}^{g}\right)\right)\frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha(1+\delta_{CO2}^{m})^n}}{\left(\left(\beta_1 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha}\right)\left(\beta_2 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha(1+\delta_{CO2}^{m})^n}\right) - \frac{\left([i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2\right)^2}{4\alpha^2(1+\delta_{CO2}^{m})^n}\right)\left(\beta_1 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha}\right)} \quad (18)$$

Accordingly, this leads to an equilibrium price in period two of:

$$E(p_2^{CO2}) = \frac{-\theta_2\,\beta_1 - (\theta_1+\theta_2)\frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha} - \gamma\,\beta_1\left(C\, i_{CO2}^{c} + G\, i_{CO2}^{g}\right)}{\left(\beta_1 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha}\right)\left(\beta_2 + \frac{[i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2}{2\,\alpha(1+\delta_{CO2}^{m})^n}\right) - \frac{\left([i_{CO2}^{c}]^2 + \left[i_{CO2}^{g}\right]^2\right)^2}{4\,\alpha^2(1+\delta_{CO2}^{m})^n}} \quad (19)$$

In equilibrium, CO_2 prices decrease with increasing surplus parameters θ_1 and θ_2 and with increasing emission responsiveness parameters β_1 and two β_2. If the hedging volume by power firms increases in period one and adds to the surplus in period two, the price in period one increases and decreases in period two.

Equilibrium in case of speculative demand

In case two, speculators expect that the carbon price will increase at a rate above or equal to their return requirements, $\delta_{CO2}^{e} \geq \delta_{CO2}^{s}$. To simplify the calculations we assume $\varphi \to \infty$. Combining $\delta_{CO2}^{e} = \delta_{CO2}^{s}$ with the allowance balance across the periods

$$\theta_1 + \beta_1\, p_1^{CO2} + \theta_2 + \beta_2\, E(p_2^{CO2}) = 0 \quad (20)$$

provides the equilibrium prices $p_1^{CO2^*}$ and $E(p_2^{CO2})^*$:

$$p_1^{CO2^*} = \frac{-(\theta_1+\theta_2)}{\beta_1 + \beta_2(1+\delta_{CO2}^{s})^n} \quad (21)$$

$$E(p_2^{CO2})^* = \frac{-(\theta_1 + \theta_2)(1 + \delta_{CO2}^s)^n}{\beta_1 + \beta_2(1 + \delta_{CO2}^s)^n} \quad (22)$$

The higher that the required rate of return by speculators δ_{CO2}^s is, the lower that prices are in equilibrium.

3.4.2 Parameterisation of CO_2 emitters, hedgers and speculators

To calibrate the model, we use the parameters in Table 3.3. We calibrate the surplus parameters θ_1 and θ_2 and the emission responsiveness parameters β_1 and β_2, so that the surplus $Q_1^{surplus}$ matches the CO_2 hedging volume Q_1^h of 1.4 billion tonnes of CO_2 and banking is pursued at modest discount rates of 5%. This corresponds to the implied discount rates from EU ETS impact assessments. These assumed a price of 30 Euro for 2020 at the beginning of the second trading period. Given a 2008 price of about 20 Euro, this implies an annual discount rate of more than 3% (EU, 2008b; DECC, 2009).

The hedging flexibility by power firms in the four-period model ranges from 1.1 to 1.7 billion tonnes of CO_2. This holds if firms apply discount rates of 0-10% to price expectations and a given α that reflects firm's sensitivity to deviations from the hedging schedule. To translate the same range of flexibility into the simplified two-period framework, we reduce the parameter α to 0.00001 Euro/GWh. The hedging schedule γ of 150% corresponds to the 84% of power hedged one year in advance, 46% two years in advance and 20% three years in advance.

In the EU ETS, the third trading period covers eight years from 2013 to 2020. Therefore, we consider price equilibriums for the case that one period in our two-period model corresponds to eight years $n = 8$. Moreover, the emissions' responsiveness to prices is assumed to increase in period two, $\beta_2 > \beta_1$, as in the long term firms can adapt to CO_2 prices through investment choices.

Table 3.4: Parameter assumptions of demand-supply model

Parameter	**Unit**	**Value**
θ_1	Billion t CO_2	1.1
θ_2	Billion t CO_2	-2.5
β_1	Billion tCO_2^2/ Euro	0.020
β_2	Billion tCO_2^2/ Euro	0.050
γ	%	150
δ_{CO2}^m	%	5
n	Years	8
α	Euro /GWh	0. 00001
δ_{CO2}^s	%	15

3.4.3 Quantification of carbon price impact

The two-period model of CO_2 hedgers, emitters and speculators can demonstrate how current carbon prices relate to current demand and supply of allowances, future scarcity, and discount rates applied to expected carbon prices.

Figure 3.4 depicts price equilibriums for different surplus levels in period one. The prices in market equilibrium decrease with the surplus of CO_2 allowances. As the surplus in period one increases, the discrepancy between today's price and price expectations widens and the discount rates that market participants apply to price expectations increase. This discrepancy amplifies as one period corresponds to eight years and therefore discounting multiplies by eight. Providing the cumulative surplus is below the 1.7 billion tonnes of CO_2 that can be absorbed by hedgers (black lines), discount rates below 10% are obtained. For surpluses above this level, the current price decreases and discount rates increase to 15%, so that speculative investors enter the market and stabilise the discount rate that applies with further increases of the surplus in period one at this level (slope change in black lines).

This change in discount rates applied to price expectations contrasts with economic models that assume unlimited availability of banking at discount rates of 5% (grey lines). These models do not differentiate between the different types of investors banking CO_2 allowances.

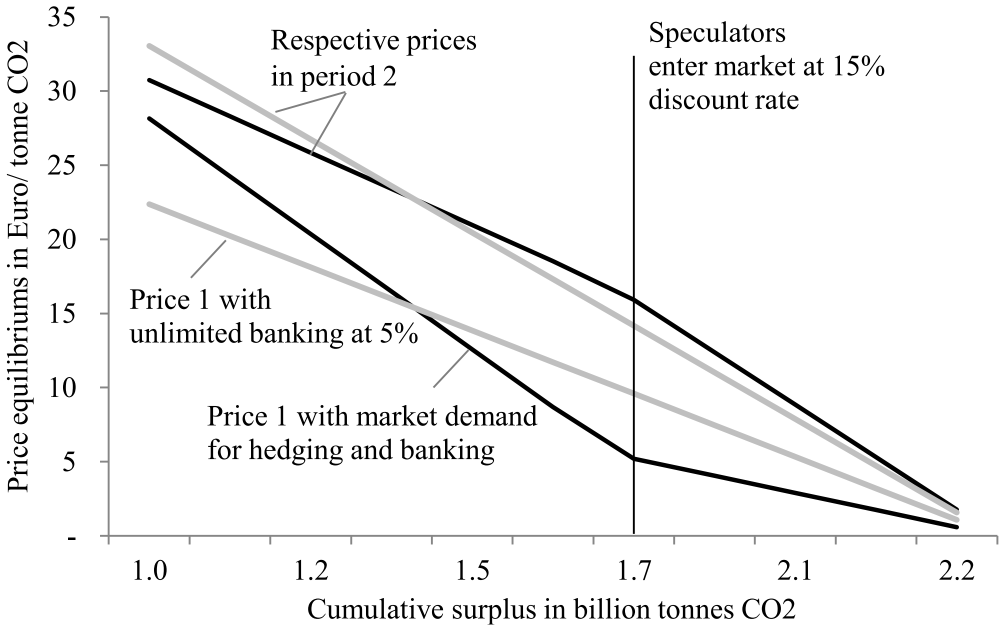

Figure 3.4: Price equilibriums for different surplus levels

To illustrate how the model can help explain recent price developments in the EU ETS, we apply it to a situation where the surplus exceeds CO_2 hedging by power firms, and speculative investment in CO_2 allowances is required to balance the market. In the EU ETS, the cumulative surplus is estimated to be 2.2 billion tonnes of CO_2 in 2012 and is expected to reach 2.6 billion tonnes of CO_2 by 2015 (Neuhoff et al., 2012). In order to return to a situation where banking can be pursued at discount rates in the order of 5%, the surplus needs to be reduced.

Figure 3.5 shows carbon price developments for the market equilibrium with speculators, and two policy options for reducing the surplus, backloading and a permanent set-aside. In the market equilibrium with speculators, the surplus amounts to 2.2 billion tonnes of CO_2. This corresponds to our actual surplus estimate for 2012. Since the surplus exceeds hedging demand by power firms, the remaining surplus allowances are banked as speculative investment. Therefore, the current price decreases, so that speculators can expect to earn annual rates of return of 15%.

Backloading 0.9 billion tonnes of CO_2 from period one to period two, as proposed by the European Commission (2012c), reduces the volume of CO_2 allowances that needs to be banked in period one. This means that surplus allowances can be absorbed by hedgers and prices in period one increase slightly. Since the retained CO_2 allowances are released in period two, price expectations decrease.

Setting aside 0.9 billion tonnes of CO_2 in period one also reduces the surplus so that it can be absorbed by hedgers. Since allowances are permanently retained, prices increase in period one and two. This allows banking for hedging purposes at low discount rates.

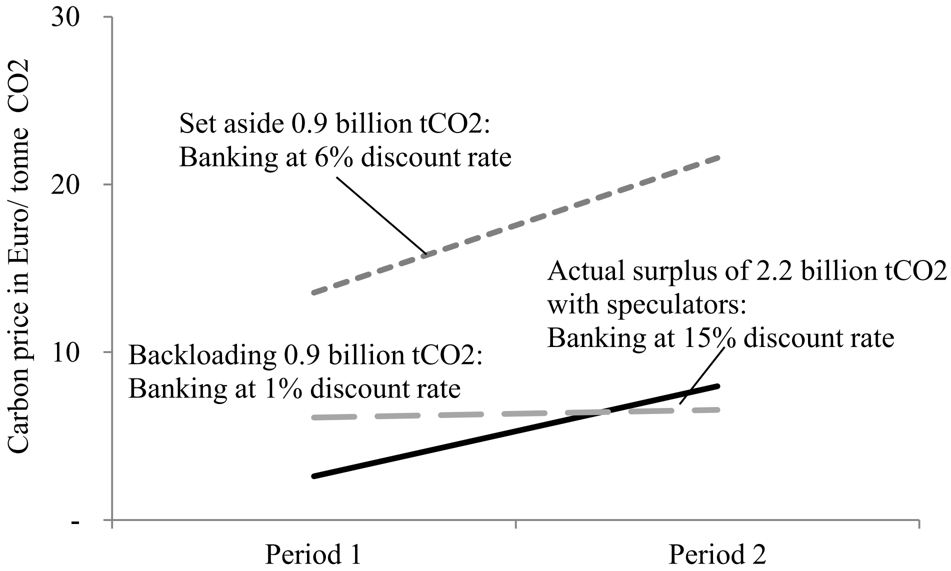

Figure 3.5: Impact of policy options on discounting of price expectations

These calculations are subject to a degree of uncertainty owing to the limited data available. The industry sector has not been considered. However, industry may have also banked a few million CO_2 allowances. Between 2008 and 2010 industrial emitters received 569 million CO_2 allowances gratis beyond their need to cover annual emissions.

Furthermore, our CO_2 hedging estimate of 1.4 billion tonnes CO_2 relies on hedging strategies and power production data from 2010 annual reports and a survey of power hedging carried out by Eurelectric. Several factors may impact the hedging level. First, power production has decreased by 3% since 2010. Second, changes in the power market and the forward contracting have an impact on CO_2 hedging volumes. For example, with shares in renewable energy on the increase, the need for forward contracting for coal and CO_2 allowances will fall.

Keeping these caveats in mind, we present a simple analytic framework to demonstrate the EU ETS price dynamics accounting for different types of actors who banks EU ETS surplus allowances.

3.5 Conclusion

One benefit of banking, as highlighted in the literature, is that market participants can smooth emission mitigation costs over time. This means that if the surplus is high and prices are low they can bank allowances for future use when they expect prices to be higher. Banking can thereby help to stabilise carbon prices and contribute to intertemporal efficiency.

We differentiate two types of banking, i.e. hedging and speculation. Market participants can bank CO_2 allowances to meet future compliance obligations. As CO_2 allowances do not have any storage cost, banks can buy CO_2 allowances at the spot market and offer forward contracts up to 3-4 years ahead of delivery to hedging firms at a price that covers their opportunity cost of capital. This carbon arbitrage is reflected in forward contract prices being traded on average at 5% discount above spot prices in the second trading period. In a situation where surplus allowances exceed hedging needs, CO_2 allowances are banked as a speculative investment. Speculative investors, however, require higher rates of return to cover the risks associated with future carbon price developments. This implies that long term carbon price expectations are highly discounted and thus can depress current prices.

To illustrate this effect, we model the different types of banking in a simple two period demand and supply model. Two main factors that determine the volume of CO_2 hedging by European power firms are identified, recording information from 13 interviews: On the one hand, the CO_2 hedging volume depends on the volume of power sold forward, which is a corporate strategy decision that can be adjusted when forward prices deviate significantly from expectations determined within firms. On the other hand, power firms can hedge with an emphasis on one specific generation technology when this is supported by attractive forward prices - both for carbon and for other fuels. This flexibility can result in adjustments to the CO_2 hedging volume in a range of 1.1 to 1.7 billion tonnes by the end of 2012, for discount rates of 0-10%. We then model the interactions between CO_2 hedging by power firms, CO_2 banking by speculative investors and CO_2 price dependent emission levels in a two-period framework. As the surplus increases, the discrepancy between today's price and price expectations widens and the discount rates applied to price expectations increase.

Further analysis is required to determine the type of reforms needed to guarantee that the surplus stays within limits where banking can be pursued at modest discount rates. In particular, uncertainties remain around the variance of actual emissions, the responsiveness of emissions to prices and the overall impact of the forward contracting market if CO_2 hedging opportunities change. One way of reducing exposure to external shocks, such as the financial crisis, would be to determine the emission cap for allowances not for twelve years ahead, as was done in 2008 for the period up to 2020, but rather for shorter time frames. For example, Australia allows an adjustment of the cap every five years and the Regional Greenhouse Gas Initiative in the US is able to do so every three years. This could ensure that the emissions cap was more closely aligned with the actual emission trajectory.

3.6 Appendix

Appendix A

The Lagrangian of the four period model is:

$$\max_{c_1,g_1,r_1,c_2,g_2,r_2,c_3,g_3,r_3,\lambda_1,\lambda_2,\lambda_3} L \tag{A1}$$
$$= \max_{c_1,g_1,r_1,c_2,g_2,r_2,c_3,g_3,r_3,\lambda_1,\lambda_2,\lambda_3} (c_1 + g_1 + r_1)\, p_1^e\, (1+\delta_e^m)^4 + (c_2 + g_2 + r_2)\, p_1^e\, (1+\delta_e^m)^3 (1+\delta_e^e)^1$$
$$+ (c_3 + g_3 + r_3)\, p_1^e\, (1+\delta_e^m)^2 (1+\delta_e^e)^2$$
$$+ (C - c_1 - c_2 - c_3 + G - g_1 - g_2 - g_3 + R - r_1 - r_2 - r_3)\, p_1^e\, (1+\delta_e^m)^1 (1+\delta_e^e)^3$$
$$-c_1 (p_1^c / f^c\, (1+\delta_c^m)^4 + i_{CO2}^c\, p_1^{CO2} (1+\delta_{CO2}^m)^4)$$
$$- c_2 (p_1^c / f^c\, (1+\delta_c^m)^3 (1+\delta_c^e)^1 + i_{CO2}^c\, p_1^{CO2} (1+\delta_{CO2}^m)^3\, (1+\delta_{CO2}^e)^1)$$
$$- c_3 (p_1^c / f^c\, (1+\delta_c^m)^2 (1+\delta_c^e)^2 + i_{CO2}^c\, p_1^{CO2} (1+\delta_{CO2}^m)^2\, (1+\delta_{CO2}^e)^2)$$
$$- (C - c_1 - c_2 - c_3)(p_1^c / f^c\, (1+\delta_c^m)^1 (1+\delta_c^e)^3 + i_{CO2}^c\, p_1^{CO2} (1+\delta_{CO2}^m)^1\, (1+\delta_{CO2}^e)^3)$$
$$- g_1 \left(p_1^g / f^g \left(1+\delta_g^m\right)^4 + i_{CO2}^g\, p_1^{CO2} (1+\delta_{CO2}^m)^4 \right)$$
$$- g_2 \left(p_1^g / f^g \left(1+\delta_g^m\right)^3 \left(1+\delta_g^e\right)^1 + i_{CO2}^g\, p_1^{CO2} (1+\delta_{CO2}^m)^3\, (1+\delta_{CO2}^e)^1 \right)$$
$$- g_3 \left(p_1^g / f^g \left(1+\delta_g^m\right)^2 \left(1+\delta_g^e\right)^2 + i_{CO2}^g\, p_1^{CO2} (1+\delta_{CO2}^m)^2\, (1+\delta_{CO2}^e)^2 \right)$$
$$- (G - g_1 - g_2 - g_3) \left(p_1^g / f^g \left(1+\delta_g^m\right)^1 \left(1+\delta_g^e\right)^3 + i_{CO2}^g\, p_1^{CO2} (1+\delta_{CO2}^m)^1\, (1+\delta_{CO2}^e)^3 \right)$$
$$-\alpha ((\gamma_1\, C - c_1)^2 + (\gamma_2\, C - c_1 - c_2)^2 + (\gamma_3\, C - c_1 - c_2 - c_3)^2$$
$$+ (\gamma_1\, G - g_1)^2 + (\gamma_2\, G - g_1 - g_2)^2 + (\gamma_3\, G - g_1 - g_2 - g_3)^2 + (\gamma_1\, R - r_1)^2 + (\gamma_2\, R - r_1 - r_2)^2$$
$$+ (\gamma_3\, R - r_1 - r_2 - r_3)^2)$$
$$+\lambda_1 (C - c_1 - c_2 - c_3) + \lambda_2 (G - g_1 - g_2 - g_3) + \lambda_3 (R - r_1 - r_2 - r_3)$$

The first order (Karush–Kuhn–Tucker) conditions are the following:

$$\frac{\partial L}{\partial c_1} \tag{A2}$$
$$= p_1^e ((1+\delta_e^m)^4 - (1+\delta_e^m)^1 (1+\delta_e^e)^3) - p_1^c / f^c\, ((1+\delta_c^m)^4 - (1+\delta_c^m)^1 (1+\delta_c^e)^3)$$
$$- i_{CO2}^c\, p_1^{CO2} ((1+\delta_{CO2}^m)^4 - (1+\delta_{CO2}^m)^1\, (1+\delta_{CO2}^e)^3) + 2\alpha (\gamma_1\, C - c_1) + 2\alpha (\gamma_2\, C - c_1 - c_2)$$
$$+ 2\alpha (\gamma_3\, C - c_1 - c_2 - c_3) - \lambda_1 = 0$$

$$\frac{\partial L}{\partial c_2} \tag{A3}$$
$$= p_1^e ((1+\delta_e^m)^3 (1+\delta_e^e)^1 - (1+\delta_e^m)^1 (1+\delta_e^e)^3)$$
$$- p_1^c / f^c\, ((1+\delta_c^m)^3 (1+\delta_c^e)^1 - (1+\delta_c^m)^1 (1+\delta_c^e)^3)$$
$$- i_{CO2}^c\, p_1^{CO2} ((1+\delta_{CO2}^m)^3\, (1+\delta_{CO2}^e)^1 - (1+\delta_{CO2}^m)^1\, (1+\delta_{CO2}^e)^3) + 2\alpha (\gamma_2\, C - c_1 - c_2)$$
$$+ 2\alpha (\gamma_3\, C - c_1 - c_2 - c_3) - \lambda_1 = 0$$

$$\frac{\partial L}{\partial c_3} \tag{A4}$$
$$= p_1^e ((1+\delta_e^m)^2 (1+\delta_e^e)^2 - (1+\delta_e^m)^1 (1+\delta_e^e)^3)$$
$$- p_1^c / f^c\, ((1+\delta_c^m)^2 (1+\delta_c^e)^2 - (1+\delta_c^m)^1 (1+\delta_c^e)^3)$$
$$- i_{CO2}^c\, p_1^{CO2} ((1+\delta_{CO2}^m)^2\, (1+\delta_{CO2}^e)^2 - (1+\delta_{CO2}^m)^1\, (1+\delta_{CO2}^e)^3) + 2\alpha (\gamma_3\, C - c_1 - c_2 - c_3) - \lambda_1$$
$$= 0$$

$$\frac{\partial L}{\partial g_1} = p_1^e((1+\delta_e^m)^4 - (1+\delta_e^m)^1(1+\delta_e^e)^3) - p_1^g/f^g\left(\left(1+\delta_g^m\right)^4 - \left(1+\delta_g^m\right)^1\left(1+\delta_g^e\right)^3\right) - i_{CO2}^g\, p_1^{CO2}((1+\delta_{CO2}^m)^4 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3) + 2\alpha(\gamma_1\, G - g_{14}) + 2\alpha(\gamma_2\, G - g_1 - g_2) + 2\alpha(\gamma_3\, G - g_1 - g_2 - g_3) - \lambda_2 = 0 \quad \text{(A5)}$$

$$\frac{\partial L}{\partial g_2} = p_1^e((1+\delta_e^m)^3(1+\delta_e^e)^1 - (1+\delta_e^m)^1(1+\delta_e^e)^3) - p_1^g/f^g\left(\left(1+\delta_g^m\right)^3\left(1+\delta_g^e\right)^1 - \left(1+\delta_g^m\right)^1\left(1+\delta_g^e\right)^3\right) - i_{CO2}^g\, p_1^{CO2}((1+\delta_{CO2}^m)^3\,(1+\delta_{CO2}^e)^1 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3) + 2\alpha(\gamma_2\, G - g_1 - g_2) + 2\alpha(\gamma_3\, G - g_1 - g_2 - g_3) - \lambda_2 = 0 \quad \text{(A6)}$$

$$\frac{\partial L}{\partial g_3} = p_1^e((1+\delta_e^m)^2(1+\delta_e^e)^2 - (1+\delta_e^m)^1(1+\delta_e^e)^3) - p_1^g/f^g\left(\left(1+\delta_g^m\right)^2\left(1+\delta_g^e\right)^2\right) - i_{CO2}^g\, p_1^{CO2}((1+\delta_{CO2}^m)^2\,(1+\delta_{CO2}^e)^2 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3) + 2\alpha(\gamma_3\, G - g_1 - g_2 - g_3) - \lambda_2 = 0 \quad \text{(A7)}$$

$$\frac{\partial L}{\partial r_1} = p_1^e((1+\delta_e^m)^4 - (1+\delta_e^m)^1(1+\delta_e^e)^3) + 2\alpha(\gamma_1\, R - r_{14}) + 2\alpha(\gamma_2\, R - r_1 - r_2) + 2\alpha(\gamma_2\, R - r_1 - r_2 - r_3) - \lambda_3 = 0 \quad \text{(A8)}$$

$$\frac{\partial L}{\partial r_2} = p_1^e((1+\delta_e^m)^3(1+\delta_e^e)^1 - (1+\delta_e^m)^1(1+\delta_e^e)^3) + 2\alpha(\gamma_2\, R - r_1 - r_2) + 2\alpha(\gamma_2\, R - r_1 - r_2 - r_3) - \lambda_3 = 0 \quad \text{(A9)}$$

$$\frac{\partial L}{\partial r_3} = p_1^e((1+\delta_e^m)^2(1+\delta_e^e)^2 - (1+\delta_e^m)^1(1+\delta_e^e)^3) + 2\alpha(\gamma_2\, R - r_1 - r_2 - r_3) - \lambda_3 = 0 \quad \text{(A10)}$$

$$\frac{\partial L}{\partial \lambda_1} = C - c_1 - c_2 - c_3 \geq 0, \qquad \lambda_1 \geq 0, \qquad (C - c_1 - c_2 - c_3)\lambda_1 = 0 \quad \text{(A11)}$$

$$\frac{\partial L}{\partial \lambda_2} = G - g_1 - g_2 - g_3 \geq 0, \qquad \lambda_2 \geq 0, \qquad (G - g_1 - g_2 - g_3)\lambda_2 = 0 \quad \text{(A12)}$$

$$\frac{\partial L}{\partial \lambda_3} = R - r_1 - r_2 - r_3 \geq 0, \qquad \lambda_3 \geq 0, \qquad (R - r_1 - r_2 - r_3)\lambda_3 = 0 \quad \text{(A13)}$$

$$c_1, c_2, c_3, g_1, g_2, g_3, r_1, r_2, r_3 \geq 0 \quad \text{(A14)}$$

If expectations of future prices differ from forward contracts for CO_2 allowances $\delta_{CO2}^e \neq \delta_{CO2}^m$, but expectation for power, coal and gas match forward contracts for these commodities, solving for the volumes of coal, gas and non-fossils yields:

$$c_1 = -\frac{i_{CO2}^{c}\, p_1^{CO2}}{6\alpha}((1+\delta_{CO2}^{m})^4 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_1}{6\alpha} + \frac{\gamma_1\, C + \gamma_2\, C - c_2 + \gamma_3\, C - c_2 - c_3}{3} \quad \text{(A15)}$$

$$c_2 = -\frac{i_{CO2}^{c}\, p_{14}^{CO2}}{4\alpha}((1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_1}{4\alpha} + \frac{\gamma_2\, C - c_1 + \gamma_3\, C - c_1 - c_3}{2} \quad \text{(A16)}$$

$$c_3 = -\frac{i_{CO2}^{c}\, p_1^{CO2}}{2\alpha}((1+\delta_{CO2}^{m})^2\,(1+\delta_{CO2}^{e})^2 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_1}{2\alpha} + \gamma_3\, C - c_1 - c_2 \quad \text{(A17)}$$

$$g_1 = -\frac{i_{CO2}^{g}\, p_1^{CO2}}{6\alpha}((1+\delta_{CO2}^{m})^4 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_2}{6\alpha} + \frac{\gamma_1\, G + \gamma_2\, G - g_2 + \gamma_3\, G - g_2 - g_3}{3} \quad \text{(A18)}$$

$$g_2 = -\frac{i_{CO2}^{g}\, p_1^{CO2}}{4\alpha}((1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_2}{4\alpha} + \frac{\gamma_2\, G - g_1 + \gamma_3\, G - g_1 - g_3}{2} \quad \text{(A19)}$$

$$g_3 = -\frac{i_{CO2}^{g}\, p_1^{CO2}}{2\alpha}((1+\delta_{CO2}^{m})^2\,(1+\delta_{CO2}^{e})^2 - (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) - \frac{\lambda_2}{2\alpha} + \gamma_3\, G - g_1 - g_2 \quad \text{(A20)}$$

$$r_1 = -\frac{\lambda_3}{6\alpha} + \frac{\gamma_1\, R + \gamma_2\, R - r_2 + \gamma_2\, R - r_2 - r_3}{3} \quad \text{(A21)}$$

$$r_2 = -\frac{\lambda_3}{4\alpha} + \frac{\gamma_2\, R - r_1 + \gamma_3\, R - r_1 - r_3}{2} \quad \text{(A22)}$$

$$r_3 = -\frac{\lambda_3}{2\alpha} + \gamma_3\, R - r_1 - r_2 \quad \text{(A23)}$$

To solve for c_1, c_2 and c_3, equations (A15) - (A17) can be written in matrix form:

$$\begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} = \begin{pmatrix} -\frac{i_{CO2}^c\, p_1^{CO2}((1+\delta_{CO2}^m)^4 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3)}{6\alpha} - \frac{\lambda_1}{6\alpha} + \frac{(\gamma_1+\gamma_2+\gamma_3)C}{3} \\ -\frac{i_{CO2}^c\, p_1^{CO2}((1+\delta_{CO2}^m)^3\,(1+\delta_{CO2}^e)^1 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3)}{4\alpha} - \frac{\lambda_1}{4\alpha} + \frac{(\gamma_2+\gamma_3)C}{2} \\ -\frac{i_{CO2}^c\, p_1^{CO2}((1+\delta_{CO2}^m)^2\,(1+\delta_{CO2}^e)^2 - (1+\delta_{CO2}^m)^1\,(1+\delta_{CO2}^e)^3)}{2\alpha} - \frac{\lambda_1}{2\alpha} + \gamma_3 C \end{pmatrix} + \begin{pmatrix} 0 & -2/3 & -1/3 \\ -1 & 0 & -1/2 \\ -1 & -1 & 0 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} \tag{A24}$$

$$\Leftrightarrow C = B + A\,C$$

$$\Leftrightarrow (\mathrm{I} - \mathrm{A})\mathrm{C} = \mathrm{B}$$

$$\Leftrightarrow \begin{pmatrix} 1 & 2/3 & 1/3 \\ 1 & 1 & 1/2 \\ 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}$$

Next, we convert the matrix on the left side in a unity matrix.

$$\Leftrightarrow \begin{pmatrix} 3 & 2 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} = \begin{pmatrix} 3\,b_{14} \\ 2\,b_{24} - b_{34} \\ b_{34} \end{pmatrix} \tag{A25}$$

$$\Leftrightarrow \begin{pmatrix} 1 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} = \begin{pmatrix} 3\,b_1 \; - 4\,b_2 \; + 2\,b_3 \\ 2\,b_2 \; - b_3 \\ -2\,b_2 \; + 2\,b_3 \end{pmatrix}$$

$$\Leftrightarrow \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} c_1 \\ c_2 \\ c_3 \end{pmatrix} = \begin{pmatrix} 3\,b_1 \; - 2\,b_2 \\ -3\,b_1 \; + 4\,b_2 \; - b_3 \\ -2\,b_2 \; + 2\,b_3 \end{pmatrix}$$

Hence, c_1, c_2 and c_3, are:

$$c_1 = \frac{i_{CO2}^c}{2\alpha}\; p_1^{CO2}(-(1+\delta_{CO2}^m)^4 + (1+\delta_{CO2}^m)^3\,(1+\delta_{CO2}^e)^1) + \gamma_1\,C \tag{A26}$$

$$c_2 = \frac{i_{CO2}^c}{2\alpha}\, p_1^{CO2}((1+\delta_{CO2}^m)^4 - 2(1+\delta_{CO2}^m)^3\,(1+\delta_{CO2}^e)^1 + (1+\delta_{CO2}^m)^2\,(1+\delta_{CO2}^e)^2) - (\gamma_1 - \gamma_2)\,C \tag{A27}$$

$$c_3 = \frac{1}{2\alpha}\, i_{CO2}^{c}\, p_1^{CO2}((1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1 - 2(1+\delta_{CO2}^{m})^2\,(1+\delta_{CO2}^{e})^2 + (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) + \frac{\lambda_1}{2\alpha} - (\gamma_2 - \gamma_3)C \tag{A28}$$

Accordingly, g_1, g_2 and g_3, as well as r_1, r_2 and r_3 are:

$$g_1 = \frac{i_{CO2}^{g}}{2\alpha}\, p_1^{CO2}(-(1+\delta_{CO2}^{m})^4 + (1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1) + \gamma_1\, G \tag{A29}$$

$$g_2 = \frac{i_{CO2}^{g}}{2\alpha}\, p_1^{CO2}((1+\delta_{CO2}^{m})^4 - 2(1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1 + (1+\delta_{CO2}^{m})^2\,(1+\delta_{CO2}^{e})^2) - (\gamma_1 - \gamma_2)\, G \tag{A30}$$

$$g_3 = \frac{i_{CO2}^{g}}{2\alpha}\, p_1^{CO2}((1+\delta_{CO2}^{m})^3\,(1+\delta_{CO2}^{e})^1 - 2(1+\delta_{CO2}^{m})^2\,(1+\delta_{CO2}^{e})^2 + (1+\delta_{CO2}^{m})^1\,(1+\delta_{CO2}^{e})^3) + \frac{\lambda_2}{2\alpha} - (\gamma_2 - \gamma_3)\, G \tag{A31}$$

$$r_1 = \gamma_1\, R \tag{A32}$$

$$r_2 = -(\gamma_1 - \gamma_2)\, R \tag{A33}$$

$$r_3 = \frac{\lambda_3}{2\alpha} - (\gamma_2 - \gamma_3)\, R \tag{A34}$$

Appendix B

GAMS code of CO_2 hedging model

```
Scalars
pe1          Price of elec for year 1 (EUR per MWh)
/51.4/

pc1          Price of coal for year 1 (EUR per MWh)
/12.1/

pg1          Price of gas for year 1 (EUR per MWh)
/26.9/

pco1         Price of CO2 for year 1 (EUR per tCO2)
/20/

gamma1       Strategy in  3 years ahead
/0.20/

gamma2       Strategy in 2 years ahead
/0.46/

gamma3       Strategy in 1 year ahead
/0.84/

Ccap         Annual coal capacity(MWh)
/639103440/

Gcap         Annual gas capacity(MWh)
/718991370/

Rcap         Annual RES capacity (MWh)
/1295260000/

ic           CO2 intensity of coal(tCO2 per MWh)
/0.96/

ig           CO2 intensity of gas(tCO2 per MWh)
/0.41/

fc           Efficiency of coal
/0.408/

fg           Efficiency of gas
/0.551/
```

```
alfa          Risk aversion
/0.00000000845/

deltam        Market rate
/0.05/

deltae        Expected discount rate (Base case)
/0.05/

deltamco      Market rate of CO2
/0.05/

deltaeco      Expected discount rate of CO2
/0.05/
;

Positive Variables
c1            Coal volume 1 (MWh)
c2            Coal volume 2 (MWh)
c3            Coal volume 3 (MWh)
g1            Gas volume 1 (MWh)
g2            Gas volume 2 (MWh)
g3            Gas volume 3 (MWh)
r1            Res volume 1 (MWh)
r2            Res volume 2 (MWh)
r3            Res volume 3 (MWh)
lambda1       Dual variable for coal
lambda2       Dual variable for gas
lambda3       Dual variable for res
;

Equations
KKT_c1          KKT of objective function wrt coal 1
KKT_c2          KKT of objective function wrt coal 2
KKT_c3          KKT of objective function wrt coal 3
KKT_g1          KKT of objective function wrt gas 1
KKT_g2          KKT of objective function wrt gas 2
KKT_g3          KKT of objective function wrt gas 3
KKT_r1          KKT of objective function wrt res 1
KKT_r2          KKT of objective function wrt res 2
KKT_r3          KKT of objective function wrt res 3
KKT_lambda1     KKT of objective function wrt lambda1
KKT_lambda2     KKT of objective function wrt lambda2
KKT_lambda3     KKT of objective function wrt lambda3
;

KKT_c1..
        -pe1*(power((1+deltam),4)-(1+deltam)*power((1+deltae),3))
```

```
        +(pc1/fc)*(power((1+deltam),4)-((1+deltam)*power((1+deltae),3)))
        +ic*pco1*(power((1+deltamco),4)-(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma1*Ccap-c1)-2*alfa*(gamma2*Ccap-c1-c2)
        -2*alfa*(gamma3*Ccap-c1-c2-c3)
        -lambda1=g= 0;

KKT_c2..
        -pe1*(power((1+deltam),3)*(1+deltae)-(1+deltam)*power((1+deltae),3))
        +(pc1/fc)*(power((1+deltam),3)*(1+deltae)
        -(1+deltam)*power((1+deltae),3))
        +ic*pco1*(power((1+deltamco),3)*(1+deltaeco)
        -(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma2*Ccap-c1-c2)-2*alfa*(gamma3*Ccap-c1-c2-c3)
        -lambda1=g= 0;

KKT_c3..
        -pe1*(sqr(1+deltam)*sqr(1+deltae)-(1+deltam)*power((1+deltae),3))
        +(pc1/fc)*(sqr(1+deltam)*sqr(1+deltae)-(1+deltam)*power((1+deltae),3))
        +ic*pco1*(sqr(1+deltamco)*sqr(1+deltaeco)
        -(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma3*Ccap-c1-c2-c3)-lambda1=g= 0;

KKT_g1..
        -pe1*(power((1+deltam),4)-(1+deltam)*power((1+deltae),3))
        +(pg1/fg)*(power((1+deltam),4)-(1+deltam)*power((1+deltae),3))
        +ic*pco1*(power((1+deltamco),4)-(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma1*Gcap-g1)-2*alfa*(gamma2*Gcap-g1-g2)
        -2*alfa*(gamma3*Gcap-g1-g2-g3)-lambda2=g= 0;

KKT_g2..
        -pe1*(power((1+deltam),3)*(1+deltae)-(1+deltam)*power((1+deltae),3))
        +(pg1/fg)*(power((1+deltam),3)*(1+deltae)
        -(1+deltam)*power((1+deltae),3))+ic*pco1*(power((1+deltamco),
        3)*(1+deltaeco)-(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma2*Gcap-g1-g2)-2*alfa*(gamma3*Gcap-g1-g2-g3)-lambda2=g= 0;

KKT_g3..
        -pe1*(sqr(1+deltam)*sqr(1+deltae)-(1+deltam)*power((1+deltae),3))
        +(pg1/fg)*(sqr(1+deltam)*sqr(1+deltae)-(1+deltam)*power((1+deltae),3))
        +ic*pco1*(sqr(1+deltamco)*sqr(1+deltaeco)
        -(1+deltamco)*power((1+deltaeco),3))
        -2*alfa*(gamma3*Gcap-g1-g2-g3)-lambda2=g= 0;

KKT_r1..
        -pe1*(power((1+deltam),4)-(1+deltam)*power((1+deltae),3))
        -2*alfa*(gamma1*Rcap-r1)-2*alfa*(gamma2*Rcap-r1-r2)
        -2*alfa*(gamma3*Rcap-r1-r2-r3)-lambda3 =g= 0;
```

```
KKT_r2..
        -pe1*(power((1+deltam),3)*(1+deltae)
        -(1+deltam)*power((1+deltae),3))
        -2*alfa*(gamma2*Rcap-r1-r2)-2*alfa*(gamma3*Rcap-r1-r2-r3)
        -lambda3 =g= 0;

KKT_r3..
        -pe1*(sqr(1+deltam)*sqr(1+deltae)-(1+deltam)*power((1+deltae),3))
        -2*alfa*(gamma3*Rcap-r1-r2-r3)-lambda3 =g= 0;

KKT_lambda1..
        Ccap-c1-c2-c3 =g= 0;

KKT_lambda2..
        Gcap-g1-g2-g3 =g= 0;

KKT_lambda3..
        Rcap-r1-r2-r3 =g= 0;

Model hedging_model /KKT_c1.c1, KKT_c2.c2, KKT_c3.c3, KKT_g1.g1, KKT_g2.g2,
            KKT_g3.g3,KKT_r1.r1, KKT_r2.r2, KKT_r3.r3,
          KKT_lambda1.lambda1, KKT_lambda2.lambda2, KKT_lambda3.lambda3/

Solve hedging_model using MCP;

display c1.l, c2.l, c3.l, g1.l, g2.l, g3.l, r1.l, r2.l, r3.l,
        lambda1.l, lambda2.l, lambda3.l;
```

Appendix C

The market equilibrium in period one is:

$$Q_1^{surplus} - Q_1^h - Q_1^s = 0 \tag{A35}$$

Solving the market equilibrium for the price in period one in the case of no speculative demand yields:

$$\Leftrightarrow \theta_1 + \beta_1 \, p_1^{CO2} - \left(\frac{1}{2\alpha} \, i_{CO2}^c \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2} \right) + \gamma C \right) i_{CO2}^c - \left(\frac{1}{2\alpha} \, i_{CO2}^g \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2} \right) + \gamma \, G \right) i_{CO2}^g = 0 \tag{A36}$$

$$\Leftrightarrow p_1^{CO2} = - \frac{\theta_1 - \gamma\left(C \, i_{CO2}^c + G \, i_{CO2}^g\right) - \frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}}{\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}}$$

The market equilibrium in period two is:

$$Q_2^{surplus} + Q_1^h + Q_1^s = 0 \tag{A37}$$

Solving the market equilibrium in period two for the price in period two in case of no speculative demand yields:

$$\Leftrightarrow \theta_2 + \beta_2 \, E(p_2^{CO2}) + \left(\frac{1}{2\alpha} \, i_{CO2}^c \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2} \right) + \gamma \, C \right) i_{CO2}^c + \left(\frac{1}{2\alpha} \, i_{CO2}^g \left(\frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n} - p_1^{CO2} \right) + \gamma \, G \right) i_{CO2}^g = 0 \tag{A38}$$

$$\Leftrightarrow E(p_2^{CO2}) = \frac{-\theta_2 - \gamma\left(C \, i_{CO2}^c + G \, i_{CO2}^g\right) + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha} p_1^{CO2}}{\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}}$$

Plugging in the price in period one p_1^{CO2} in equation (A38), the equilibrium price in period two can be written as:

$$\Leftrightarrow E(p_2^{CO2}) = \frac{-\theta_2 - \gamma\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)}{\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}} + \frac{\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\left(-\frac{\theta_1 - \gamma\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right) - \frac{E(p_2^{CO2})}{(1+\delta_{CO2}^m)^n}\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}}{\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}}\right)}{\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}} \tag{A39}$$

$$\Leftrightarrow E(p_2^{CO2}) = \frac{-\theta_2\,\beta_1 - (\theta_1+\theta_2)\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha} - \gamma\,\beta_1\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)}{\left(\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\right)\left(\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}\right) - \frac{\left([i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2\right)^2}{4\,\alpha^2(1+\delta_{CO2}^m)^n}}$$

The price in period two $E(p_2^{CO2})$ can be used to solve for the equilibrium price in period one p_1^{CO2}:

$$\Leftrightarrow p_1^{CO2} = \frac{-\theta_1 + \gamma\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)}{\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}} + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n} * \frac{\frac{-\theta_2\,\beta_1 - (\theta_1+\theta_2)\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha} - \gamma\,\beta_1\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)}{\left(\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\right)\left(\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}\right) - \frac{\left([i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2\right)^2}{4\,\alpha^2(1+\delta_{CO2}^m)^n}}}{\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}} \tag{A40}$$

$$\Leftrightarrow p_1^{CO2} = \frac{-\theta_1 + \gamma\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)}{\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}} + \frac{\left(-\theta_2\,\beta_1 - (\theta_1+\theta_2)\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha} - \gamma\,\beta_1\left(C\, i_{CO2}^c + G\, i_{CO2}^g\right)\right)\frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}}{\left(\left(\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\right)\left(\beta_2 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha(1+\delta_{CO2}^m)^n}\right) - \frac{\left([i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2\right)^2}{4\,\alpha^2(1+\delta_{CO2}^m)^n}\right)\left(\beta_1 + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\right)}$$

4. Incentives of regional policymakers to use EU funds for EU objectives

Anne Schopp

The amount of EU funding policymakers have at their disposal is not trivial. One fifth of the 2014-2020 EU budget is attributed to the European energy and climate targets. This raises the question of how the EU budget process can ensure that regional policymakers dedicate this money to low carbon options. Taking Germany as a case study, this paper examines the 2007-2013 EU funded programmes of two financially important funds. Interviews with regional policymakers show that the formulation of the programmes is crucial to integrate European objectives in the regional decision making process. In this process step, regional policymakers allocate funds to thematic priorities using two unlinked accounting systems, financially binding programme-specific priority axes on the one hand and indicative EU defined expenditure categories on the other hand. Requiring policymakers to specify a dedicated priority axis for low carbon investments can be effective in shifting funding away from known investment fields towards low carbon investments. After programme approval, the regional ministries are flexible in its implementation and the selection criteria that they apply. The monitoring process can balance the incentives for regional policymakers to use EU money flexibly, in response to market and policy developments during the seven year budget framework.

Keywords: EU budget; EU objectives; Policy process; Implementation; Regional programmes

4.1 Introduction

The amount of EU funding that policymakers have at their disposal is not trivial. The 2007-2013 budget added up to nearly one trillion Euro, almost half of which is directly implemented by the member states. This budget is the financial vehicle at EU level to implement European objectives. The relevance of the specific objectives changes with each budget period. While the EU energy and climate targets have not played a major role in previous budgets, one fifth of the 2014-2020 budget is attributed to them (EU, 2011b). Whether the funds will achieve these targets depends on the incentives and requirements for policymakers at regional level to shift their strategies away from known investment fields such as road transport and general business support towards new low carbon investments.

Using Germany as a case study, this paper examines to what extent EU funding is effective in incentivising regional policymakers to link the budget to European objectives. To do so, interviews were conducted with regional policymakers on the policy process of two funds, the European Regional Development Fund (ERDF) and the European Agriculture Fund for Rural Development (EAFRD). The funds were selected because the European Commission envisages using them as financial vehicles for the EU climate and energy targets in the budget period 2014-2020. Furthermore, the ERDF as part of EU Cohesion Policy and the EAFRD as part of EU Agricultural Policy are financially important. In Germany, some states received up to a quarter of their investment-related budget from the two funds (Figure 4.1). The states implement these funds through regional programmes. Therefore, the focus is on the decision making process related to these programmes.

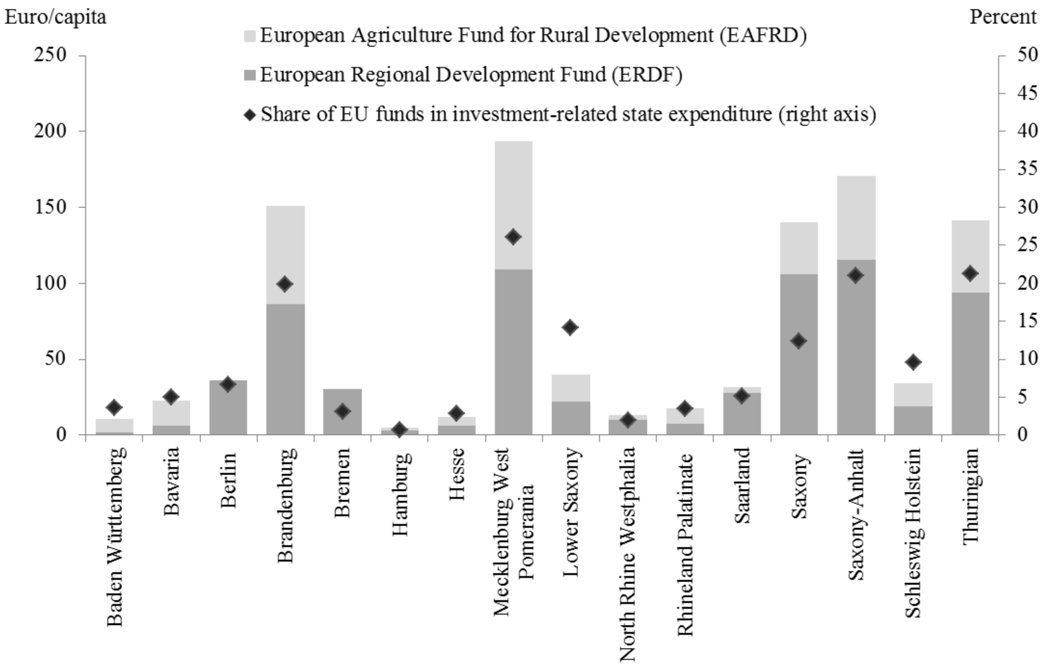

Figure 4.1: EU funding in German states in 2010
Sources: Based on Destatis (2011b), Destatis (2011a), BMWi (2007), BMELV (2009)

To date, evidence of regions implementing the budget effectively remains thin (Bachtler and Mendez, 2007; Begg, 2010). This paper aims to contribute to fill this gap by examining the implementation of EU funds through regional programmes. It is the first analysis to provide empirical findings on the decision making process in Germany related to the formulation, implementation, monitoring and evaluation of these programmes in the period 2007-2013. This can inform the debate on how to design the policy process in order to link the budget to the EU climate and energy targets in the 2014-2020 period.

The results show first that the formulation of the regional programmes was crucial to reflect European objectives in the regional strategies. In this process stage, regional policymakers were required to allocate funds to a variety of themes related to innovation, entrepreneurship, transport, energy or environment using two unlinked accounting systems: priority axes and EU defined expenditure categories. According to the interviews, priority axes were a more effective tool than expenditure categories to integrate EU objectives into the decision making process at regional level. This is due to the fact that financial commitments under these priority axes were binding. Furthermore, they were programme-specific and therefore could be aligned with existing regional strategies.

Second, the programmes were a synthesis of existing regional strategies, regional needs, programmes of the previous budget period and European objectives. Regional policymakers reported that they were able to prioritise those dimensions that were closely linked to the Lisbon Strategy such as innovation. This is because quantified objectives on research and development spending and earmarking provisions aligned the ERDF at EU level with the Lisbon Strategy. This in turn enlarged the bargaining power of those regional policymakers who aimed at pursuing related priorities in the discussions between ministries.

Third, the regional ministries were mainly responsible to implement the programmes. They were flexible in specifying project selection criteria, once the European Commission had approved the programme. Therefore, the alignment of project selection with the European objectives depended also on the eligible measures and funding criteria that regional policymakers apply.

The remainder of the paper is structured as follows: Section 2 reviews the literature on the effective use of EU funding. Section 3 describes the methodology used to interview regional experts on the decision making process during formulation, implementation, monitoring and evaluation of the programmes. Along these stages, section 4 presents the results from the interviews on the incentives and requirements of integrating EU objectives into the decision making process at regional level. Section 5 discusses the findings in the light of the 2014-2020 EU budget period where part of the funds is linked to the EU energy and climate targets. Section 6 draws conclusions.

4.2 Literature

Previous analyses bring to the fore several dimensions when examining whether the funding is effective in achieving its multiple objectives. Econometric studies assess its effectiveness by quantifying the impact of EU funds on European objectives of economic growth or employment. Positive growth effects are found in the member states that are endowed with ‘good institutions’ (Ederveen et al., 2006) and strong roles for the regions (Bähr, 2008). Both factors apply to Germany. Eggert et al. (2007) find that EU structural funds led to higher growth in the East German states, although, on average, the economic growth rate declined in Germany. One drawback of the econometric approach is that it ignores the channels through which the funds impact EU objectives. However, these channels reveal to what extent the design of the funds is effective in integrating EU objectives into regional programmes – the main concern of this paper.

Several studies in the field of political economy address this gap by assessing the effectiveness of the policy process related to the funds’ implementation. One channel that received great attention in the literature is the impact of the European Commission on the funds’ use. Bachtler et al. (2003) examine the implementation of the ERDF in several EU regions, including North Rhine-Westphalia. They find that the European Commission triggered an increase in long term strategic planning and collaboration for regional development policy across sectors and institutions. Bachtler et al. (2007) also emphasise this strategic influence of the European Commission on regional implementation. Thus, the European Commission was able to modify programmes in terms of financial allocation between priorities, choice of indicators and quantification of objectives. Over time, the authors argue, the European Commission shifted its influence from the programme to the strategic level. At the same time Mendez (2011) demonstrates that the alignment of the EU funds with the European objectives was particularly strong in countries having similar objectives. For example, Spain and France shifted their EU funding to European objectives such as research and innovation, since national policies were targeting similar objectives.

Another channel between the EU funds and their contribution to European objectives is the impact of non-state actors. Lang (2003), for example, conducted interviews with experts to assess the effectiveness of such cooperation in several member states, including North Rhine-Westphalia and Berlin during the 1990s in Germany. For both states the analysis shows that non-state actors, such as interest group representatives did not play a strong role in formulating and implementing the programmes. However, their involvement was stronger when the regions formulated the programmes for the 2000-2006 budget period.

Lang (2003) highlights the role of the ministry leading the implementation of EU funds at regional level as a further important channel. In Germany, the ERDF was initially managed exclusively by the regional economic ministries and closely linked to national ‘Joint task’ funding which is provided by the national economics ministry to enterprises. As a consequence, the fund focused primarily on business support. Over time the fund was more and more used to support existing regional strategies. This means it started to support also objectives in the fields of environment and research and therefore other regional ministries gained some responsibilities to manage part of the funding. (Lang, 2003; Heinelt et al., 2005).

To date, empirical findings on the policy process at regional level are scarce (Bachtler et al., 2007; Begg, 2010). This paper aims to contribute to the literature by examining incentives and requirements of regional policymakers to integrate EU objectives into regional programmes. To do so, each stage of the policy process is analysed in detail.

4.3 Interview methodology

The interviews covered the policy process related to the funds' implementation at regional level as outlined in Figure 4.2. The European institutions formulate strategies, regulations and guidelines for seven-year periods. Based on these, the regional ministries implement the funds through regional programmes in three stages: First, they formulate programme strategies, second they implement these strategies and third they monitor and evaluate their programmes. Other relevant actors in this policy process include the European Commission, national ministries and regional partners who are represented in the monitoring committee.

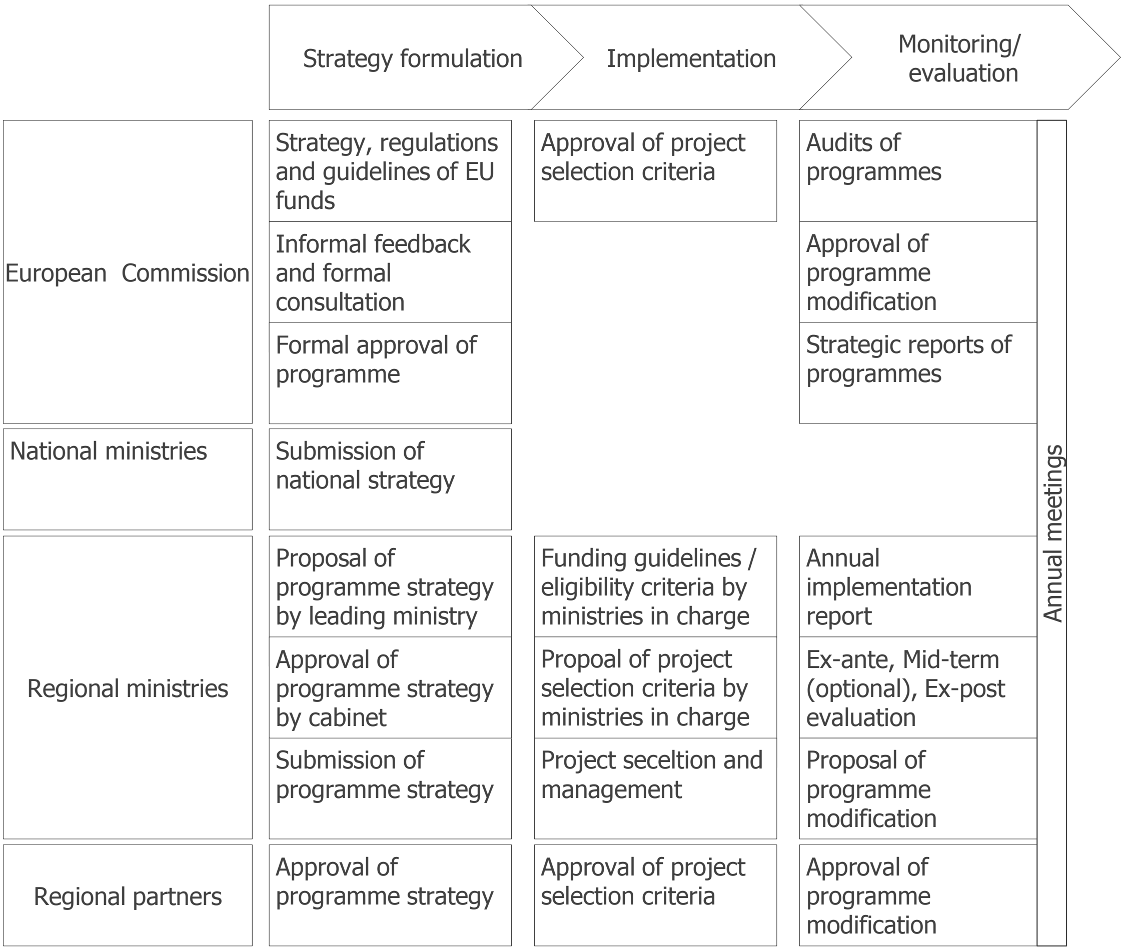

Figure 4.2: Interview structure along process stages of regional programmes

The selection of experts was based on purposive sampling (McCracken, 1988). This means the interviews targeted regional policymakers, since they are mainly responsible for the implementation of the funds. In Germany, 30 authorities manage EU funded programmes: 16 ERDF programmes and 14 EAFRD programmes (two federal city states do not have rural development programmes of their own). Of these authorities 24 representatives were interviewed. To capture the perspective of other stakeholders in the process of formulating and implementing regional programmes, interviews were conducted with six representatives of participating ministries and two regional partners. So overall, the analysis was informed by 32 interviews with regional experts in 2011 and 2012. [3]

The interviews were semi-structured (Gläser and Laudel, 2009). The guideline included both open and quantitative questions (see Appendix). For example, interviewees assessed quantitatively the relevance of a set of factors to the decision making at regional level. Some interviewees assigned similar scores to these factors rather than rank their importance in the decision process. Therefore, some of the quantitative results are not statistically significant, even though the interviewees qualitatively ranked their importance.

4.4 Results of the 2007-2013 programmes

Based on the interviews, the incentives and requirements of the various actors can be outlined as follows: In the period 2007-2013, the European Commission was interested in using the EU budget as financial vehicle to implement European objectives. Moreover, it was required to demonstrate to other European institutions that the funds are spent effectively. In Germany, the national ministries acted more as representatives of the states. The regional ministries in turn were interested in getting as much funding as possible to realise their existing strategies and to have sufficient flexibility for the following seven years to accommodate economic changes or strategic changes due to, for example, a change in the regional government. At the same time they were required to find an agreement among the different stakeholders at regional level and to get approval by the European Commission for their programme strategy. Those of the regional stakeholders whose objectives were in line with European objectives wanted the strategy formulated at European level to be stringent, since this could enlarge their bargaining power in regional negotiations.

The policy process related to the programmes is explained in more detail in the following paragraphs which are devoted to the individual stages of the process, i.e. strategy formulation, implementation, monitoring and evaluation.

[3] Interviews were conducted with representatives of the managing authorities of the ERDF in Baden Württemberg, Bavaria, Berlin, Brandenburg, Bremen, Hamburg, Hesse, Mecklenburg West Pomerania, Lower Saxony, North Rhine Westphalia, Rhineland Palatinate, Saarland, Saxony, Schleswig-Holstein and Thuringian. For the EAFRD, interviews were conducted with managing authorities in Baden Württemberg, Bavaria, Brandenburg, Hesse, Mecklenburg West Pomerania, Lower Saxony, North Rhine Westphalia, Rhineland Palatinate and Thuringian. In addition, participating regional ministries in Brandenburg and regional partners in Mecklenburg West Pomerania were interviewed.

4.4.1 Strategy formulation

In order to receive EU funding, the regions set up programmes for each of the funds. These programmes should be in line with the strategies, regulations and guidelines that the European institutions agreed on for the EU funds. In the budget period 2007-2013, part of the funds was used to contribute to the Lisbon Strategy. Most prominently, this EU strategy aimed at increasing research and development (R&D) expenditure at 3% of GDP (EU, 2010b).

Funding allocation
Under the ERDF, the German states faced two types of commitments in order to formulate the programme strategy: First, they had the binding commitment to allocate funding on priority axes (thematic priorities). If regional policymakers wanted to shift funding from one priority axis to another during the budget period, they required European Commission approval. The interviewees reported that they preferred a lower number of priority axes, since this increased the flexibility to shift money within an axis. The priority axes were not EU standardised, but programme-specific. In this way priority axes offered the opportunity to reflect existing regional strategies in the programmes and enhanced domestic ownership.

Second, regional policymakers had the indicative commitment to spend funding on 86 EU defined expenditure categories. The European Commission used these categories to show how money was spent in the member states at aggregate level. In the period 2007-2013, the expenditure categories were the main tool to link the ERDF to the Lisbon Strategy. In Germany, some 75% of ERDF funding was earmarked for projects that are bookable in one of the 47 Lisbon relevant categories in the fields of research, innovation, business and others (EU, 2006a).

Figure 4.3 shows that priority axes are the most relevant factor in formulating the strategy (standard error of 0). According to the interviews, specifying priority axes mattered more than the commitment of spending funding on expenditure categories; however, the expenditure categories were not ranked statistically differently. The regional ministries reported that they were a rather formal commitment. Furthermore, the accounting systems, priority axes and expenditure categories, were not linked to each other. Since the German states did not allocate the expenditure categories to the priority axes, they did not use the categories to specify the priority axes in greater detail. It was reported that this provided some flexibility for the use of the funds during the budget period.

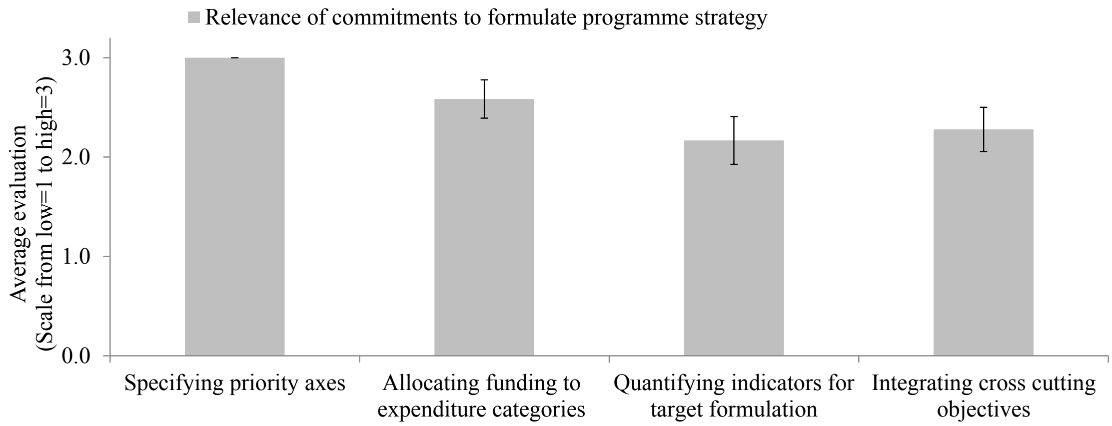

Figure 4.3: Relevance of commitments to formulate programme strategy
Sources: Interviews with 11 ERDF managing authorities. Note: EAFRD managing authorities do not use expenditure categories and are therefore excluded. Quantitative evaluations were considered only from managing authorities to allow comparability.

The EAFRD programmes were not explicitly linked to the Lisbon Strategy. However, the strategy of the programmes was fixed at four thematic themes. In the period 2007-2013, the regional ministries had to spend a minimum of 10% on projects in the field of agriculture competitiveness, at least 25% on agriculture sustainability, 10% on life quality and economic diversification as well as 5% on projects involving local rural communities. Each thematic theme encompassed a predefined set of measures. In contrast to the ERDF programmes, the regional policymakers had to specify detailed information not only for each of the four priority axis, but also for each of the 40 measures (EU, 2005). Hence, the ministries were less flexible to design the strategy of the EAFRD programmes.

In case of the ERDF, the budget was shared between the economics ministry in charge of the programme and other regional ministries for infrastructure, research or environment. Typically, each priority axis was assigned to one ministry. The budget of the EAFRD stayed primarily within the agriculture ministry. The financial allocation between priority axes and ministries was usually agreed by cabinet decision.

With regard to the negotiations between ministries, interviewees managing ERDF programmes repeatedly stressed the strong focus on innovation during strategy formulation between ministries for the 2007-2013 period. Some reported that they were able to prioritise those dimensions that were closely linked to the Lisbon Strategy such as innovation. This is because EU wide quantified objectives on research and development spending and Lisbon earmarking provisions enlarged their bargaining power. As a result, all 16 states included a separate priority axis for research and innovation for the 2007-2013 cycle compared to five states in the period 2000-2006. The expenditure categories, which were only introduced in 2007, also show that the majority of funding applies to categories related to research and innovation (Figure 4.4).

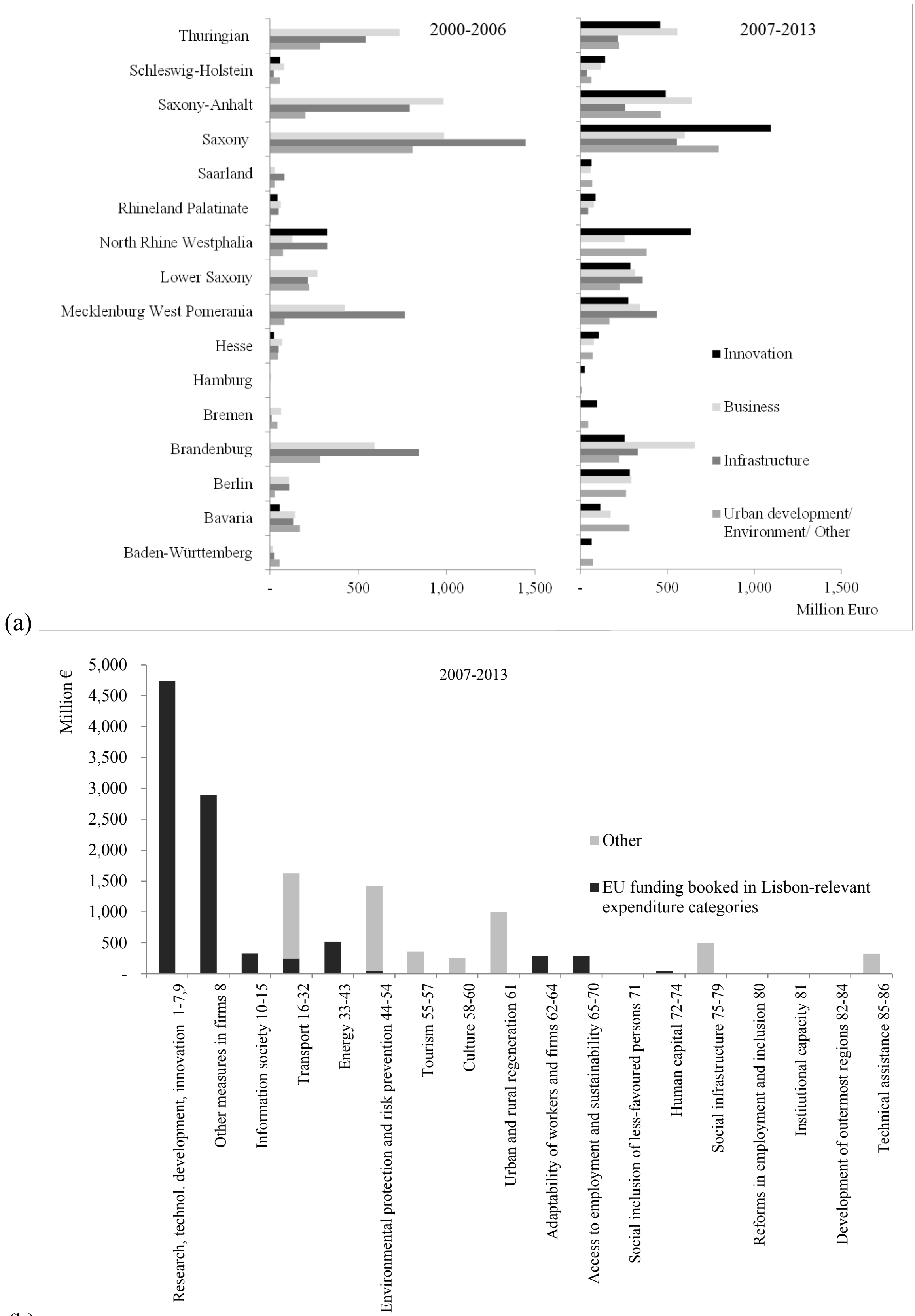

Figure 4.4: ERDF allocation to (a) priority axis and (b) expenditure categories
Sources: Own depiction based on ERDF regional programmes of German states 2000-2006 and 2007-2013

Approval process
For both funds, the regional monitoring committees had to approve the programmes. They consisted of representatives of regional ministries, national ministries, the European Commission and regional partners who represented different interest groups. To what extent regional partners influenced the programmes varied across states. In Mecklenburg West Pomerania, the regional partners were closely engaged in the programme formulation of the ERDF and the EAFRD. In the ERDF, for example, they supported the design of priority axes through measure-specific criteria such as the inclusion of ‘land use’ and ‘avenue tree protection’ for transport. In other states, regional partners were less involved in the strategy formulation. Across states interviewees appraised the discussions with different actors when mapping out the strategies. However, the managing authority in the lead ministry was the actor with the greatest bargaining power at regional level, as they entered the discussions with the European Commission.

To get approval by the European Commission, the regional lead ministries usually informally exchanged on critical aspects with the responsible EU officer of DG Regional Policy or DG Agriculture and Rural Development. The formal Commission approval required an interdepartmental consultation. The interviewees evaluated the transparency of this approval process and the associated criteria differently. In the negotiations over the ERDF programmes, the European Commission frequently proposed to increase the number of priority axes in order to shift the financial allocation toward a clear priority, e.g. environment. Six states, Bavaria, Brandenburg, Lower Saxony, Mecklenburg West Pomerania, Schleswig Holstein, and Thuringia, reported that they included a separate priority axis on environment to obtain programme approval. Furthermore, the European Commission proposed increasing or reducing funding for certain priorities. Lower Saxony, for example, allocated less funding for road construction as initially envisaged. The proposals by the European Commission also related to more measure-specific details beyond financial allocation such as limiting the eligibility of business support to small- and medium-sized enterprises (SMEs). However, Thuringia argued in favour of expanding the business support to bigger companies and finally succeeded. These examples illustrate to what extent the European Commission influenced the programme strategy at this stage of the policy process. It was reported however that the European Commission was not able to change the overall strategy of a programme and its influence got the smaller, the closer the negotiation was to the start of the budget period.

Most interviewees reported that the programmes were – in contrast to annual budget plans – an instrument to pursue long term strategies at regional level, since they were formulated for a period of seven years. At the same time all regional policymakers highlighted their interest in flexibility during these years to accommodate economic as well as governmental changes.

4.4.2 Implementation

Responsibility for implementing the programme lied with the regional ministries. Typically, each regional ministry formulated funding guidelines, selected and supervised projects for its share of the EU budget. The funding guidelines specified eligibility criteria and selection procedures. For both funds, they were not subject to approval by the European Commission. This provided some flexibility to regional ministries in order to implement the programmes.

In addition to the eligibility criteria, the regional ministries formulated selection criteria, which had to be approved by the regional monitoring committee (EU, 2006a). In Mecklenburg West Pomerania, for example, the regional partners requested that the ministries included selection criteria of avenue tree protection for transport measures. Their request was successful because the regional partners had integrated these criteria already during programme formulation and therefore could refer to this agreed strategy. This illustrates the importance to reflect European objectives in the programmes early on.

However, the project selection criteria had limited impact, since they principally took effect if the available funding was not sufficient to support all eligible projects. Admittedly, for some priorities it was the opposite: The number of eligible projects was not sufficient to exhaust the available financial support.

During implementation of both funds, regional policymakers had to consider the cross-cutting objectives of environmental protection, gender equality and non-discrimination. Cross-cutting objectives were pursued through selection criteria rather than through dedicated priority axes. This means no funding was dedicated to these objectives in advance. The interviews indicate that cross-cutting objectives played a significantly lesser role than other objectives in project selection (p-value <0.05) and that current practices differed across German states (Figure 4.5).

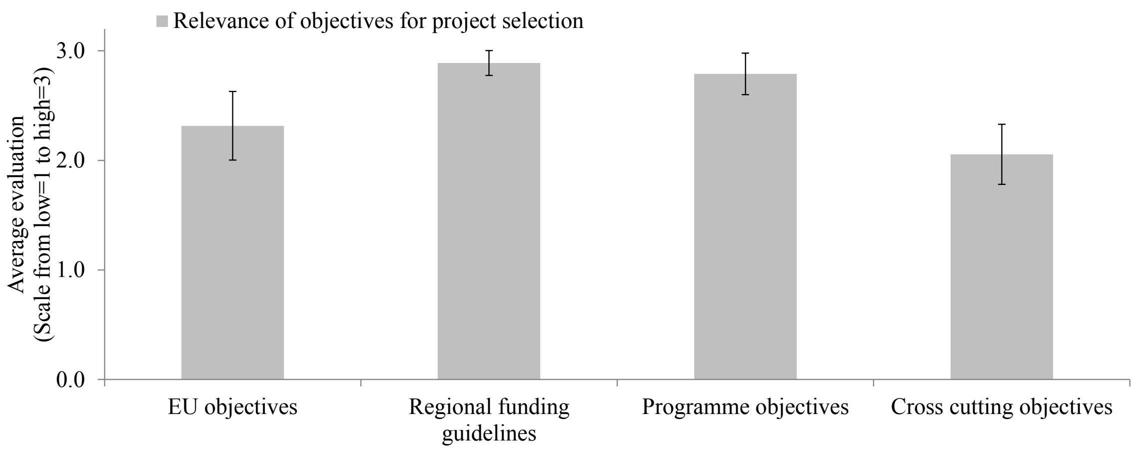

Figure 4.5: Relevance of objectives for project selection
Sources: Interviews with 18 ERDF and EAFRD managing authorities

The regional funding guidelines in turn mattered most for project selection. Therefore, these guidelines and the associated funding criteria that regional policymakers apply influenced to what extent the programmes reflected European objectives during implementation.

4.4.3 Monitoring and evaluation

During implementation the regional ministries were required to monitor the projects and report to the monitoring committee. Therefore, regional policymakers published an annual progress report for each programme which then had to be approved by the monitoring committee. The interviewees stated that they used the report mainly to control whether the disbursement of financial flows was on track with the planned figures.

In case of the ERDF, the report contained information on the outflow of funds for each priority axis and expenditure category. The interviewees stressed the limited validity of the expenditure categories for tracking EU funding, since each project was allocated to one category, even if the project addressed multiple objectives. There were also no consistent criteria for booking projects to these categories. However, this was the tool to achieve Lisbon earmarking targets. In addition to financial flows, output indicators were reported for each priority axis. Hence, the priority axis was also used as the main tool to monitor outcomes.

In the monitoring report of the EAFRD programmes, regional policymakers had to give more detailed information: they provided not only financial outflows, but also output indicators for each priority axis as well as each measure. Furthermore, EU wide output and result indicators had been specified to allow comparability across EAFRD programmes (EU, 2006c). At the same time it was reported that the tracking system involved costs and therefore the managing authority introduced minimum spending thresholds for new measures in order to ensure the IT system paid off.

According to the interviewees, there have been few programme modifications and high compliance with agreed programmes. Substantial programme modifications required approval by the European Commission. This offered another channel for the European Commission to influence the implementation of the programme. For example, regional ministries in Brandenburg reported that in 2004 they negotiated with the European Commission about shifting 80 million Euro from the priority axis environment to business support. To obtain approval also from DG Environment they agreed to introduce project criteria of sustainability in exchange. As a result Brandenburg's business promotion bank developed an evaluation method that included economic, social and ecologic criteria (ILB, 2006). However, both the economic as well as the environment ministry reported that these criteria were not yet fully adapted into project selection.

In contrast to the EAFRD, midterm evaluations of the ERDF programmes were optional. As a consequence, not all German states conducted midterm evaluations of their programmes. These evaluations were needed to obtain European Commission approval for programme modification during the implementation (EU, 2007). After the budget period has elapsed, the regional ministries will pursue *ex-post* evaluations of their programmes and the European Commission will pursue *ex-post* evaluations of each fund.

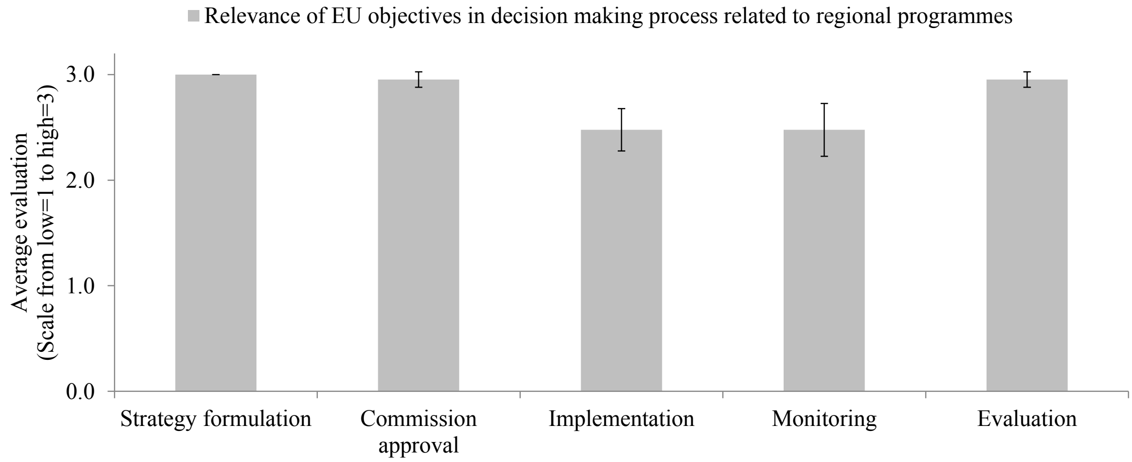

Figure 4.6: Relevance of EU objectives in policy process related to programmes
Sources: Interviews with 20 ERDF and EAFRD managing authorities

The analysis of the policy process at regional level shows that the European Commission aimed to influence primarily strategy formulation. Figure 4.6 indicates that the importance of EU objectives was significantly higher during programme formulation than implementation ($p\text{-value}<0.05$). Following approval by the European Commission, the regions were responsible to implement the programme and were flexible in concretising priority axes and project selection.

4.5 Implications for linking the 2014-2020 budget to climate targets

The European Commission proposed to closely link the 2014-2020 budget to the Europe 2020 strategy (EU, 2011b). This link can strengthen its influence on the strategies that are pursued regionally. Responsibility for formulating and implementing the regional programmes, however, stays with the regions.

According to the European Commission proposal, regions focus their programme-specific priority axes on eleven thematic objectives of the ERDF. By linking each priority axis to one of these EU defined thematic objectives and each EU defined expenditure category to one priority axis, the two parallel systems are aligned. Funds can be shifted from one category to the next only if they are in the same priority axis (EU, 2011a). This strengthens the system of expenditure categories, as regional policymakers have to use this accounting system to specify the priority axes in greater detail.

To focus the ERDF on the Europe 2020 strategy, the European Commission proposed quotas for four thematic objectives. At least 80% of the funding (60% in less developed regions) shall address the three thematic objectives of (i) research, technological development and innovation; (ii) competitiveness of SMEs; and (iii) shift towards a low carbon economy. 20% (6% in less developed regions) is earmarked for the low carbon economy objective (EU, 2011g). The analysis of the 2007-2013 programmes indicates that requiring policymakers to specify dedicated priority axes on low carbon investments can be effective in overcoming inertia and integrating new investment fields into regional strategies. However, the European Commission does not specify which priorities can be funded under the low carbon economy objective. Thus, in the case of energy efficiency investments, for example, regional policymakers decide whether the building's insulation or also the renewal of the roof is eligible for support under the low carbon objective. These choices matter for the actual energy savings resulting from EU funding. To what extent the ERDF will contribute to the Europe 2020 energy and climate targets therefore also depends on the eligible measures and funding criteria that apply to the low carbon objective.

The link of the EAFRD to the EU energy and climate targets is less stringent according to the proposal. Each rural development programme is supposed to spend at least 25% on climate change mitigation and adaptation as well as land management (EU, 2011f). However, this is not further defined.

Furthermore, the commitment to integrate cross-cutting objectives, such as sustainable development and gender equality, into the regional programmes is relatively similar to the current regulation (EU, 2011g). The experiences of the 2007-2013 budget period show that this can lead to reduced importance of the cross-cutting objectives compared to other objectives.

In order to track climate funding, the European Commission proposes the use of so-called Rio Markers. According to this methodology the expenditure categories are marked as 100%, 40% or 0% climate related (EU, 2011b). Thus, the Rio Markers can enhance transparency and provide a tool to show how much EU funding is actually spent on climate related projects at aggregate level. However, there exist still no criteria in order to allocate projects consistently to the expenditure categories. Hence, it is up to regional policymakers to decide which project should be booked in which category.

4.6 Conclusion

In contrast to annual budget plans, the EU budget's seven-year framework offers the opportunity to pursue long term strategies at regional level by creating consistency across each step of the decision making process, from programme formulation through implementation and monitoring to evaluation.

The review of the experiences in the budget period 2007-2013 shows:

The formulation of programme strategies was crucial to reflect EU objectives in regional strategies. In this process stage, regional policymakers allocated funds to thematic priorities using two unlinked accounting systems, programme-specific priority axes on the one hand and EU defined expenditure categories on the other hand. The findings demonstrate that priority axes were more effective tools than investment categories to integrate EU objectives into the decision making process at regional level, since financial commitments under these thematic priorities were binding. At the same time they were programme-specific and could be aligned with regional strategies. Expenditure categories were perceived as a rather formal commitment by some regional policymakers. This tool was used by the European Commission to show how money is spent in the member states at aggregate level.

Once the programme had been approved by the European Commission, regional policymakers decided on the implementation of the programmes mainly according to regional priorities and funding rules. Therefore, the eligible measures and funding criteria applied by regional policymakers influenced to what extent European objectives were reflected in the budget. Furthermore, regional policymakers pursued the commitment to integrate cross-cutting objectives such as sustainable development and gender equality through project selection criteria rather than through dedicated priority axes. This means no funding was dedicated to these objectives in advance. However, it was reported that cross-cutting objectives played a significantly lesser role than other objectives in project selection.

The strategies as formulated in the regional programmes were a synthesis of existing regional strategies, regional needs, programmes of the previous budget period and the EU framework. For instance, by aligning the ERDF with the Lisbon Strategy through quantified objectives on research and development spending and earmarking provisions, regional policymakers were able to prioritise those dimensions that were closely linked to the EU strategy such as innovation.

Experience gleaned from the 2007-2013 programmes indicates that requiring policymakers to specify financially binding priority axes in line with the EU energy and climate objectives can be effective in shifting funding away from known investment fields towards low carbon investments. At the same time, the strategic alignment is closely related to how regional policymakers use requirements, such as the 20% climate quota, to formulate the programme strategies and come up with ideas for measures that fit both EU objectives and existing regional strategies. The monitoring process can balance incentives for regional policymakers to use EU money flexibly in response to market and policy developments during the seven year budget framework.

4.7 Appendix

Guideline of semi-structured interviews

Part I. Formulation of policy objectives at EU level

1. From your perspective, are the EU policy objectives clearly formulated?

2. To what extent have the EU policy objectives enhanced certain regional priorities?

3. How relevant were the EU objectives for each step of your decision making process?

Relevance	High	Middle	Low
Programme formulation	☐	☐	☐
Commission approval	☐	☐	☐
Implementation	☐	☐	☐
Monitoring	☐	☐	☐
Evaluation	☐	☐	☐
Other (Please describe)	☐	☐	☐

Part II. Formulation of policy objectives at national and regional levels

4. Which objectives did you advocate in negotiating with other regional stakeholders?

5. What was the basis of discussion in these negotiations?

6. How did negotiations for EU funding differ from budget debates for state funding?

7. What mattered most for formulating the programme strategy?

Relevance	High	Middle	Low
Need to specify thematic priority axes	☐	☐	☐
Requirements to allocate funding to investment categories	☐	☐	☐
Need to find quantitative indicators	☐	☐	☐
Need to integrate cross-cutting objectives	☐	☐	☐
Other (Please describe)	☐	☐	☐

8. How do priority axes and investment categories differ?

9. Which priorities did you advocate in negotiations with the European Commission? Which factors mattered for their approval?

10. Was the way in which the European Commission verified whether the programme was coherent with the objectives of the fund transparent to you?

11. How was the cross-cutting objective "environment" integrated into the programme?

Part III. Implementation of the programme

12. From your perspective, which factors were of help in implementing the programme strategy, and which factors led to difficulties in implementation?

13. Does the number of project applications on average exceed the number of approved projects? If demand exceeds available funding, how is spending prioritised?

14. What matters most for project selection?

Relevance	High	Middle	Low
EU objectives	☐	☐	☐
Regional funding guidelines	☐	☐	☐
Programme objectives	☐	☐	☐
Cross-cutting objectives	☐	☐	☐
Other (Please describe)	☐	☐	☐

15. What happens with projects that do not qualify for EU funding? Do they then receive national or regional funding?

Part IV. Delivery of policy objectives

16. To what extent do the programme evaluations capture the success of the programme beyond the ability to spend funding?

17. How relevant are evaluation results for previous or existing programmes in your decision-making process?

18. Are you considering any programme modifications?

19. Which objectives of the programme are likely to be achieved?

20. From your perspective, what is the probability that the objectives of the fund will be achieved?

5. Incentives of commercial banks to finance energy efficiency

Anne Schopp

This paper investigates the incentives of commercial banks for providing energy efficiency lending. Using Germany, Bulgaria, Poland and Ukraine as case studies, interviews were conducted with banks to model their decision making related to energy efficiency. These show that energy efficiency investments differ from other lending projects for three reasons: first, information asymmetries and principal agent problems prevent energy efficiency investments. To overcome these barriers, many public banks provide energy efficiency lending at preferential rates often through commercial banks. Commercial banks reported that this allows them to gain customers. Second, energy efficiency lending is a new field of investment with unconventional revenue streams deriving from cost savings. Energy savings increase the value of the object that serves as collateral and diversify the lending portfolio. However, most banks reported that they do not consider energy efficiency specifics. Third, assessing these energy savings requires additional technical expertise. Therefore, some banks initiated cooperation with energy service providers. The model illustrates the trade-off banks face between initial transaction cost and benefits from portfolio diversification. According to these findings, two aspects are important to upscale energy efficiency lending: first, the requirement for banks to monetise energy savings to account for the benefit of low risk in the lending portfolio and, second, the need for energy efficiency programmes to reach a certain scale so that energy efficiency lending pays off.

Keywords: Commercial banks; Energy efficiency lending; Portfolio diversification; Transaction cost

5.1 Introduction

An increasing number of banks offer energy efficiency loans. These loans differ from traditional loans in that they require technical expertise to determine the potential of a project to reduce energy usage, thus creating the "savings" that will be used to repay the loan. These energy efficiency loans are increasing in popularity in part because public banks promote energy efficiency lending through commercial banks. Although there is a large literature on bank lending decisions, no known literature investigates the determinants of how banks make decisions with respect to offering energy efficiency loans.

The purpose of this paper is to examine the incentives and requirements of commercial banks related to energy efficiency lending. Germany, Bulgaria, Poland and Ukraine are used as case studies because commercial banks are active in providing energy efficiency loans in these countries. Semi-structured interviews were conducted with experts in retail banking, commercial banking and controlling from 27 banks. Furthermore, this paper models some of the factors as identified in the interviews to illustrate bank decision making: the interest earned from energy efficiency lending compared to conventional loans, transaction cost for advertising and building technical expertise, credit risk and capital constraints.

Three main differences are identified between energy efficiency investments and traditional lending project types:

First, in absence of any policy interventions, cost-effective energy efficiency investments are not realised due to various market failures and other barriers (Jaffe and Stavins, 1994; Carbon Trust, 2005). To overcome these barriers and to initiate the market, public banks provide energy efficiency lending at preferential provisions. They often do so through commercial banks so as to enhance subsequent commercial up take. In Germany, commercial banks reported that serving as an intermediary of the Kreditinstitut für Wiederaufbau (KfW), the national public bank, is attractive, because it provides the opportunity to enhance customer relationships by offering preferential energy efficiency loans in combination with their own products. In addition, some banks initiated their own energy efficiency loans. In Bulgaria, Poland and Ukraine, the European Bank for Reconstruction and Development (EBRD) provides energy efficiency loans via commercial banks. Although the loans are offered at commercial rates, they can be attractive to commercial banks since banks mainly refinance themselves through deposits and the EBRD provides longer term credit lines in addition to free technical assistance. Furthermore, banks can combine these loans with their own products.

Second, energy efficiency lending is a new field of investment with unconventional revenue streams deriving from (energy) cost savings. This requires banks to quantify risks associated with energy price developments and benefits resulting from energy savings (Palmer et al., 2012). These savings can increase the value of the building or the equipment and consequently also the value of the collateral that the bank uses to secure the loan in case of default; they can also allow for portfolio diversification and thereby reduce banks' capital requirements. According to the interviews, however, most banks do not consider energy efficiency specifics in their creditworthiness or lending portfolio assessment.

Third, energy efficiency investments require technical expertise to assess energy savings and depend on energy service markets (IPCC, 2007). In the Eastern European countries, the EBRD employs a technical assistance team that trains bankers and supports them in organizing client visits, assessing energy savings and developing the project pipeline. In Germany, KfW allocates the energy savings assessment to certified energy service providers in order to reduce transaction costs for banks. Furthermore, some regional banks reported that they initiated their own programmes with reduced interest rates for hiring local craftsman – allowing them to gain new customers through marketing campaigns or recommendation by craftsmen.

Based on the interviews, an analytic model is developed to assess the trade-off banks face between additional fixed transaction cost for demand development and benefits from portfolio diversification and associated lower capital requirements. In the model, a representative bank maximises its lending profits. The choice of the lending portfolio is constrained by the requirement to cover the associated risk with equity. To calibrate the model, information is used from the interviews. The model assumes that introducing energy efficiency loans into the lending portfolio involves some additional fixed cost for the bank. Setting up a new loan programme requires information campaigns, staff training and demand development. Once loan products have been integrated into the standard processes of a bank, transaction costs decline for each additional loan. At the same time, the composition of the lending portfolio is constrained, as the risks need to be covered by equity. This offers opportunities to reduce the credit risk associated with the portfolio through diversification. If all effects are jointly considered, energy efficiency lending can pay off for the banks, once a certain scale is achieved.

The rest of the paper proceeds as follows: Section 2 reviews the relevant literature on decision making of banks and characteristics of energy efficiency investments. Section 3 discusses findings from interviews with commercial banks on their energy efficiency lending activities in Germany, Bulgaria, Poland and Ukraine. Section 4 presents the model on banks' decision making about energy efficiency lending. Section 5 draws conclusions.

5.2 Literature

Why is energy efficiency lending specific compared to conventional bank lending? From an economic perspective, investments in energy efficiency are particular and the market might deliver an investment level below the social optimum. Previous studies identify several market failures and other barriers (IPCC, 2007):

Jaffe et al. (1994) list lack of information and split incentives between landlords and tenants as potential market failures inhibiting energy efficiency investment. Schleich et al. (2008)

underpin this argument empirically. Their findings show that split incentives between landlords and tenants due to rented office space and the lack of information about energy consumption patterns are indeed significant barriers for German firms. In addition, high investment cost, lacking awareness of potential benefits or irrational behaviour by firms and households are additional examples of barriers inhibiting investment in low carbon technologies (Carbon Trust, 2005). As a consequence, the potential of cost-effective energy efficiency measures is not fully realized (Tuominen et al., 2012).

Barriers exist not only on the demand side, but also on the supply side. From banks' perspective, energy efficiency lending is a new field of investment where revenue streams are derived from energy savings. To consider this in the credit assessment, banks need to quantify risks associated with energy price developments that impact revenue streams. Benefits resulting from decreased default probability or increased collateral value are also relevant (Hayes et al., 2011; Palmer et al., 2012). This requires expertise and a track record of successful energy efficiency projects for comparison (Hamilton, 2009).

Energy efficiency lending is also specific because technical expertise is needed to identify energy efficiency measures and assess associated energy savings (IPCC, 2007). This expertise is typically not available in banks and therefore may require efforts to train bankers or to initiate some form of cooperation with energy auditors. At the same time such cooperation can open up new business opportunities. In a survey with 500 US energy auditors, many reported that they act as gatekeeper for banks to energy efficiency financing (Palmer et al., 2011).

What determines bank energy efficiency lending decisions? In the industrial organisation literature on banking, specific energy efficiency aspects in banks' lending decisions have not been considered yet. Previous studies identify several levers that banks use to optimise their lending activities: portfolio composition, product differentiation, and capital requirement considerations.

The lending portfolio composition is an important lever for banks to gain in market share. Berger et al. (2002) argue that smaller banks pursue more relationship lending, as they have lower hierarchies and therefore can more easily use soft information about the creditworthiness of smaller companies than large banks. Indeed, De Haas et al. (2010) find empirical evidence in Eastern European and other transition countries that size is an important determinant for a bank's portfolio composition next to the ownership structure and the legal enforcement in the country.

Product differentiation can also enable banks to gain a comparative advantage and compete with other banks beyond prices. To differentiate themselves from their competitors, banks increase the number of branches, spend more on advertising or introduce new lending products. Dick (2007) shows, for instance, that with growing market size banks invest more in sunk cost on advertising, branching or geographic diversification to gain in market share.

Another factor impacting lending decisions is capital requirements. The regulator requires banks to hold more equity if they lend to more risky investments in order to prevent banks from taking too much risk and not being able to repay deposits (Dewatripont et al., 1994). Theoretical and empirical studies find that with capital requirements banks reduce lending and increase interest rates in the short term and increase capital ratios in the long term (VanHoose, 2007). Furthermore, banks can reduce their regulatory capital requirements by diversifying their lending portfolio (see Section 3.2). In a theoretical model, Winton (1999) demonstrates banks' trade-off between lower risk from diversification and higher monitoring cost. The author argues that diversification across industries pays off, if the risk of large losses associated with the loans is small; whereas monitoring is more important in case of high risks of large losses. Behr et al. (2007) analyse the portfolio composition of German banks. Thus, regional banks increased their industrial and sectoral diversification during the 1993 to 2002 period. The level of diversification remained constant in bigger banks, as they already had higher level at the beginning of the investigated period. According to the authors the development towards more diversification may have been encouraged by the revised international capital framework (Basel II).

This paper aims to contribute to the relevant energy efficiency literature by examining how the factors that previous studies identified, namely transaction cost, capital requirements and diversification are important to banks in the context of energy efficiency lending. In order to illustrate banks' decision making an analytic model, based on interviews with bankers, is used.

5.3 Interviews

To study commercial banks in greater detail, Germany, Bulgaria, Poland and Ukraine are used as case studies. In these countries public banks have been an important trigger for energy efficiency lending by commercial banks. In Germany, the German public bank, KfW, has been quite active in developing the financing and service market; in the Eastern European countries, the EBRD established dedicated energy efficiency credit lines with local banks starting in the early 1990s in order to develop financing capacities in this area. Following Gläser and Laudel (2009), semi-structured interviews were conducted with experts from 27 banks.[4] These include mainly experts from retail banking, in particular, construction financing, but also experts in commercial banking and controlling. The interviews covered questions on the types of loans, banks' motivation behind the lending portfolio, the financing conditions, the required collaterals and the capital requirements related to energy efficiency lending.

[4] Berliner Volksbank, Commerzbank, Deutsche Bank, DKB, EBRD, Frankfurter Sparkasse, GLS, Hannoversche Volksbank, Haspa, HypoVereinsbank (Unicredit), ING DiBa, ING Netherlands, KfW, Kreissparkasse Böblingen, L-Bank, Mainzer Volksbank, Nospa, Olper Sparkasse, Olper Volksbank, Sparkasse Dortmund, Sparkasse Mittelthüringen, Sparkasse Siegen, Tübinger Sparkasse, Tübinger Volksbank, Umweltbank, Volksbank Kaiserslautern-Nordwestpfalz and Volksbank Stuttgart.

5.3.1 Lending portfolio

Germany

In Germany, KfW is the main financial institution implementing energy efficiency policies. KfW has run energy efficiency programmes since the mid-1990s. In 2012, KfW committed 9.8 billion Euro to households, 3.4 billion Euro to firms and 0.3 billion Euro to municipalities for energy-efficient construction, refurbishment and technology (KfW, 2013b). In November 2013, the interest rates for these concessional loans were at 1-1.4 % per year for households and firms. Depending on the borrower and the type of investment, this is more than two percentage points below market rates. For municipalities the interest rate is 0.1% per year.[5] KfW provides these energy efficiency loans through local banks. These carry the credit risk and thus a borrower's financial creditworthiness must be in line with the local bank's requirements. However, the energy efficiency measures must be approved by a certified energy auditor and the final approval for these loans lies with KfW.

As a consequence, commercial banks across Germany provide KfW loans at preferential rates and combine them with their own financial products. For providing KfW loans, commercial banks receive a fixed margin of 0.75 percentage points from KfW over the loan duration (as in June 2013; KfW margin in the area of commercial banking is higher). In the interviews, banks reported that this margin is relatively low compared to the margins earned from standard financial products. At the same time the work intensity is relatively high, as banks have to monitor their customers' receipts of the energy efficient measures. Therefore, some banks do not offer KfW loans for smaller measures. To address this barrier, KfW allocated the main tasks that require technical expertise to energy auditors.

Banks reported that they consider KfW loans as a service to their clients allowing them to stay competitive. Furthermore, KfW loans are limited to 50,000 Euro for new buildings and up to 75,000 Euro per housing unit for refurbishment of existing buildings and therefore they are typically combined with conventional loan products. Some banks reported that KfW accounts for about a third of a typical loan. Obviously, the share between KfW and the bank's own financial products varies with the type of investment.

In retail banking, some banks also have their own energy efficiency programme. Dedicated energy efficiency programmes are mainly part of the portfolio in banks such as GLS or Umweltbank who identified energy efficiency as one of their core business activities. They offer an energy efficiency bonus on the standard housing loan in case a certain energy efficiency standard is achieved (KfW 70: 70% of annual primary energy consumption of comparable new building according to the energy saving regulation). Some regional banks initiated cooperation with local craftsmen with energy efficiency expertise. Households, for example, receive a lower interest rate when they use local craftsmen. Banks reported that these initiatives allow them to gain new customers through marketing campaigns or recommendation by craftsmen.

[5] See KfW programmes 151, 152 and 153 for households, 242, 243 and 244 for companies, 201 and 218 for municipalities for further information

In addition to the conventional construction financing, many banks introduced modernisation loans in the last few years. This might be related to the fact that KfW phased out their modernisation loans at the end of 2011 (KfW, 2013a). According to the interviews, this financial product is offered to clients who are interested in a fast loan application process or those who do not fulfil the technical energy efficiency requirements for the KfW funding; e.g. they intend to install the window themselves rather than by a certified craftsman. The modernisation loans build on the creditworthiness of the borrower and therefore do not require a mortgage and the associated notaries' cost. The smaller loans are therefore offered at higher interest rates than secured construction financing, but at lower rates than the classical consumer loan. Typically the target group are households that already have a mortgage on their building and are interested in an additional loan to modernise the house.

According to the interviews commercial banks in Germany provide several financial products that can be used to finance energy efficiency projects. In particular, this applies to constructing financing, since default rates are low and the building serves as collateral. This is not directly linked to energy efficiency considerations. However, energy efficiency investments increase the value of the building that serves as collateral.

Bulgaria, Poland and Ukraine

In several Eastern European countries, the EBRD has established a series of energy efficiency credit lines with local banks worth 1.9 billion EUR at the end of 2011 (EBRD, 2012). In each country the EBRD created one or more facilities for households or corporates and employed a technical assistance team. This assistance team supports local banks in developing a project pipeline.

The approach to integrate these credit lines into the existing loan portfolio differs across countries and banks. For example, the public bank UKR Exim in Ukraine established its own green department. In Ukraine, banks usually combine EBRD funding with their standard financial products, so that the final product is not labelled as a dedicated energy efficiency loan. This is different in Bulgaria or Poland, where the energy efficiency loans can be combined with EU funded grants and therefore local banks have an incentive to explicitly highlight the preferential rates of these loans. Also the size of the credit lines differs, depending on the country and the bank's size. In Bulgaria banks started with a credit line of 10 million Euro with the option of an increase by 10 million Euro. With bigger banks in Poland the EBRD established credit lines worth 50 million Euro or more.

The local banks receive EBRD loans at commercial rates for about five years. The EBRD loans are attractive to banks since they are longer-term than deposits, the main refinancing source. The accompanying technical assistance, which is free of charge, allows banks to offer additional service and thus gain market share. So far the technical assistance amounted to 3-3.5% of the facilities' financial volumes. This was spent on training banks' staff on technical energy efficiency aspects, organizing client events or visits to raise awareness, and energy audits to develop the project pipeline.

The level of leverage depends on many factors. In Ukraine leverage amounted to 200% because its high gas prices triggered demand for energy efficiency lending that exceeded EBRD financing. In some cases leverage may be due to a low maximum EBRD loan volume or due to investment in ancillary equipment that is not eligible for EBRD financing and therefore is supported by the bank's own lending sources. Many of the facilities are in their second phase and facilities in Bulgaria and other Eastern European countries are about to finish receiving EBRD financing. It remains to be seen to what extent commercial banks will continue to offer energy efficiency lending without public bank involvement.

5.3.2 Capital requirements

Banks have to cover a minimum share of their risk-weighted assets with equity in order to ensure that in severe circumstances with several non-performing loans the bank will be able to serve its liability. These requirements have been strengthened under the international regulatory framework for banks (Basel III): Banks must gradually increase their total capital from 8% to 10.5% of their risk-weighted assets (BIS, 2010). To calculate their regulatory capital requirements, banks can either use predetermined risk weights and external credit ratings (standardised approach) or they can use their own models (internal rating based approach) (BIS, 2005b). The calculations ultimately require that banks can cover the losses of non-performing loans with 99.9% probability. This determines a minimum share of equity so as to ensure that debt raised or bonds issued by a bank can be securely serviced (BIS, 2005a).

Two factors are important to the calculation: the correlation of the loss event with other losses and the likelihood of the loss event. With regard to the correlation, the capital calculations under the internal rating based approach assume that banks own perfectly diversified portfolios (BIS, 2006). However, banks need to measure the concentration of their lending portfolio and increase their regulatory capital if it is highly concentrated (granularity adjustment). This provides an incentive for banks to diversify across sectors, products and borrowers. This adjustment is typically applied to commercial banking, while the private retail banking is considered well diversified (BIS, 2001). Thus, energy efficiency lending could add to the diversification of a bank's lending portfolio, if it is not fully correlated with the remaining portfolio assets.

With regard to the likelihood of losses, loans for energy efficiency investments are often argued to be less likely to default compared to conventional loans. Blyth et al. (2011) find anecdotal evidence for this effect examining eight companies in a study commissioned by the EBRD. This is because the borrowers save energy and are therefore less exposed to energy price risk. If energy costs account for a significant share of total cost such as in energy intensive firms, the risk that the borrower defaults can be reduced. However, it was reported that in practice banks do not account for this effect.

In the interviews, it was also reported that projected energy savings are not considered as collateral because the value of future savings is not certain, but depends on e.g. energy price developments and therefore does not comply with financial regulation (BaFin, 2012). One interviewee also pointed out that banks cannot monetise energy savings in case of default. Energy efficiency, however, plays an indirect role in the capital requirement calculations. If loans are given to energy efficiency investments, the underlying building or machinery needs to serve as collateral. The resulting energy savings increase the value of the building or machinery. This in turn increases the value of the collateral and therefore reduces the risk exposure and ultimately the capital requirement for the bank providing the loan.

5.4 Quantification

This section outlines the model and then presents the model results illustrating banks' incentives and requirements related to energy efficiency lending.

5.4.1 Model

In the model, a bank provides two types of loans: energy efficiency, e, and conventional, c. For each loan type j the lending volumes for projects are of the same size l_j. The bank holds a portfolio of n_e loans for energy efficiency and n_c loans for conventional projects. To optimise this portfolio the bank chooses the number of projects for each loan type n_j considering revenues from lending and the associated risk and cost. The choice of the portfolio depends on the interest that the bank can charge for each loan type r_j, the transaction cost for each loan type t_j and the equity E available to the bank to cover the portfolio risks.

Interest rate

Banks charge a price in the form of interest for their financial loan products. From banking theory, we know that the interest rate banks charge results from the risk free rate, namely the rate at which banks can refinance their loans at the capital market plus a premium. The premium in turn reflects four components: the cost associated with the expected credit risk, the transaction cost related to advertising or processing the loan, the cost related to covering part of the loan with equity and a profit margin (Bösch, 2011).

In this model, the risk premium reflects the expected default cost for each project. It is assumed that this project-specific idiosyncratic risk is the same across projects of the same loan type r_{jd}. The transaction and equity cost do not only impact the interest rate, but the composition of the portfolio and are therefore modelled separately. Thus, the interest rate for each loan type is the sum of the risk free rate and the risk premium $r_j = r_f + r_{jd}$.

The expected revenue from energy efficiency loans derives from the interest rate multiplied by the lending volume across projects $r_e\, l_e\, n_e$. Alternatively, the bank can invest in conventional loans $r_c\, l_c\, n_c$. The expected lending revenue is:

$$R = r_e\, n_e\, l_e + r_c\, n_c\, l_c. \qquad (1)$$

Transaction cost

Lending for energy efficiency investments involves transaction cost. As reported in the interviews, the bank organizes, for example, information campaigns to raise awareness, trains its loan officers, initiates cooperation with energy auditors to assess energy savings or sets up processes to standardise loan applications. Some of these components also apply to conventional projects and may decrease with experience and scale.

For both types of loans the transaction costs include some fixed cost t_{fj} and some variable cost t_{vj} that can increase at a decreasing rate with the lending volume $n_j\, l_j$ in order to reflect scale effects:

$$T = t_{fe} + \sqrt{t_{ve}\, n_e\, l_e} + t_{fc} + \sqrt{t_{vc}\, n_c\, l_r}. \qquad (2)$$

Capital requirements

The portfolio decision also depends on capital requirements. According to BIS (2005a) the probability of credit losses L that are covered neither by equity E nor interest rate charges should not exceed 0.1%:

$$B = P(L \geq E) \leq 0.1\% \qquad (3)$$

In order to compute the regulatory capital, the Basel rating based approach assumes perfect diversification. In this way the capital required for a loan depends on the credit risk of the loan and not on the composition of the existing portfolio (BIS, 2006). To provide incentives for portfolio diversification, the regulatory capital is adjusted *ex post* through the granularity adjustment under Basel (see section 3.2). In this model, banks consider diversification benefits when choosing the lending portfolio, as they are assumed to anticipate this adjustment.

To estimate the probability that losses exceed the available equity B, the credit loss L needs to be defined. It is assumed that credit loss occurs to the bank when the sum of the values of the projects that the bank is lending to is lower than the bank's total lending volume, $n_e\, V_e + n_c\, V_c < n_e\, l_e + n_c\, l_c$. Hence, B can be rewritten as:

$$B = P(n_e(V_e - l_e) + n_c(V_c - l_c) \leq -E) \qquad (4)$$

Furthermore, the probability density function of the project values $f(V_e, V_c)$ needs to be specified in order to compute B. To do so, two types of risk are differentiated: concentrations in portfolios can relate to idiosyncratic risk (project-specific) and systematic risks (e.g. sectoral risks). The latter risk is the focus of this analysis and assumed to be fully correlated across all projects of the same type σ_j. The variance associated with the value of the portfolio varies however with the correlation between energy efficiency loans and conventional loans ρ_{ec}. Thus, the bank can reduce the risk of its portfolio by combining these two types of loans. It is assumed that the project values follow a bivariate normal distribution $f(V_e, V_c) =$

$\frac{1}{2\pi\sigma_e\sigma_c\sqrt{1-\rho_{ec}^2}} exp\left[-\frac{1}{2(1-\rho_{ec}^2)}\left(\left(\frac{V_e-\mu_e}{\sigma_e}\right)^2 - 2\rho_{ec}\frac{V_e-\mu_e}{\sigma_e}\frac{V_c-\mu_c}{\sigma_c} + \left(\frac{V_c-\mu_c}{\sigma_c}\right)^2\right)\right]$. Graphically, this means that B corresponds to the grey area below the straight line $V_c = \frac{n_c l_c - E - n_e(V_e - l_e)}{n_c}$ in the contour plot of the probability density function of the project values that are positively, but not perfectly correlated (Figure 5.1).

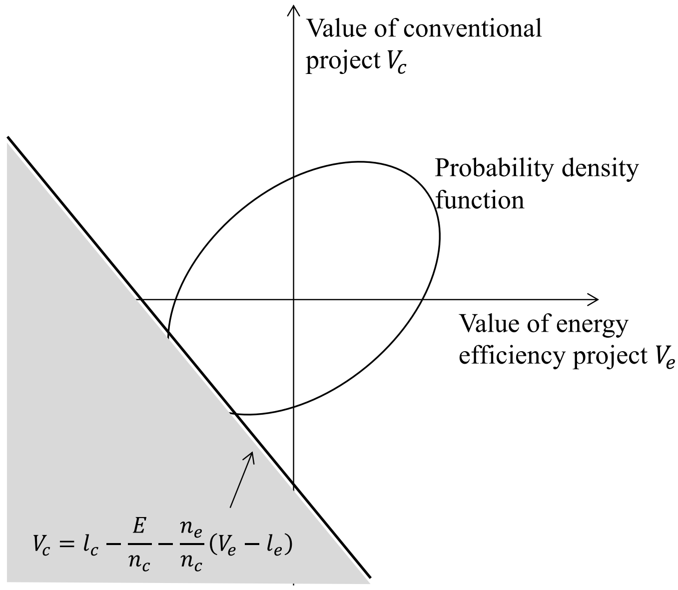

Figure 5.1: Illustration of probability density function of project values

The grey area can be calculated by integrating the probability density function to the value where $V_c = \frac{n_c l_c - E - n_e(V_e - l_e)}{n_c}$:

$$B = \int_{-\infty}^{\infty}\int_{-\infty}^{\frac{n_c l_c - E - n_e(V_e - l_e)}{n_c}} f(V_e, V_c)\, dV_c\, dV_e \qquad (5)$$

Decision problem

The bank chooses the number of projects for each loan n_j type in order to maximise profits from its lending portfolio considering the equity constraints. The decision problem of the bank is as follows:

$$\max_{n_j} P = \max_{n_j}\; r_e\, n_e\, l_e + r_c\, n_c\, l_c - t_{fe} - \sqrt{t_{ve}\, n_e\, l_e} - t_{fc} - \sqrt{t_{vc}\, n_c\, l_r}. \qquad (6)$$

s.t.

$$0.1\% \geq \int_{-\infty}^{\infty}\int_{-\infty}^{\frac{n_c l_c - E - n_e(V_e - l_e)}{n_c}} f(V_e, V_c)\, dV_c\, dV_e$$

This constrained maximisation problem cannot be solved analytically since the normal cumulative distribution function does not have a closed form. The area under the integrals, however, can be approximated by rectangles. For this purpose the decision problem is coded in Matlab (see Appendix).

5.4.2 Parameterisation

To parameterise the model, some information is used from the interviews. The energy efficiency projects that a bank provides loans for can differ substantially. In the interviews, it was reported that the financing volume and the type of borrower are different, for example, in the case of a family investing in a private residential home compared to the case of a real estate developer investing in multiple family dwellings or an energy intensive firm improving its machinery. Therefore, the reference project is stylized reflecting some common givens.

Table 5.1 summarises the parameters. In the base case portfolio, energy efficiency loans and the conventional loans have the same characteristics. The lending volume per project l_j is 1 million Euro and the number of projects for each loan type n_j is set at 100, so the overall lending volume is 200 million Euro in the base case.

The EBRD reported that it costs about 3-3.5% of the lending volume to set up a dedicated energy efficiency programme.[6] This figure is used to calibrate the initial fixed cost $t_{fj} = 2$ million Euro and the variable transaction cost parameter $t_{vj} = 0.002$ million Euro, so that the transaction cost T amounts to 7 million Euro in the base case. The assumed interest rate above the risk free rate (=0%) is 4%. Obviously, the interest rate depends on the type of investment and the underlying collateral; the assumed level of the interest rate r_j impacts merely the magnitude of the profitability, but not the direction of results.

The expected value of the project μ_j is assumed to be 1 million Euro and accordingly the expected value of lending is zero. With Basel III, banks are required to hold capital of at least 10.5% of their risk-weighted assets by 2019. Assuming a 100% weighting, the bank's overall equity E is set at 20 million Euro, i.e. 10% of the overall lending volume.

The variances σ_j and the correlation ρ_{ec} are calibrated so that the base case portfolio with $n_e = n_c = 100$ just meets the capital requirement. The two project types are assumed to be positively, but not perfectly correlated.

Table 5.1: Parameter assumptions of energy efficiency lending model

Parameter	Description	Value
l_j	Lending volume of reference project (million €)	1
t_{fj}	Fixed transaction cost of project e and c (million €)	2
t_{vj}	Variable transaction cost parameter of project e and c (million €)	0.002

[6] The EBRD estimate includes the employment of a technical assistance team, training staff of the local banks on energy efficiency aspects, organizing client events and visits to raise awareness, and energy audits to develop the project pipeline. However, transaction costs are likely to vary across institutions and countries. They depend on several factors, including the design of the energy efficiency programme, the expertise in the financial and energy service markets and demand for energy efficiency lending.

r_j	Interest rate (above risk free rate) of reference project e and c (%)	4
μ_j	Expectation of project value e and c (million €)	1
E	Equity (million €)	20
σ_j	Variance of project value e and c (million €)	0.0014
ρ_{ec}	Correlation of project e and c	0.496

These parameters are held constant in order to compare various portfolios. Therefore, the bank adjusts the number of projects for each loan type to obtain optimal portfolios with the same equity cost.

5.4.3 Results

In the model, the bank faces a trade-off between additional (fixed) transaction cost and diversification benefits when introducing an additional loan type into its lending portfolio. This applies to any new field of investment, but is especially relevant in the case of energy efficiency. Setting up a new loan programme requires information campaigns, staff training and demand development. Once loan products have been integrated into the standard processes of a bank, the transaction cost increase less and less for additional projects. Hence, banks require a certain lending scale to overcome initial transaction cost. At the same time, the composition of the lending portfolio is constrained as part of the risks need to be covered by equity. This offers opportunities to reduce the credit risk associated with the portfolio through diversification. Figure 5.2 depicts this trade-off. The net profitability for portfolios that equally meet the capital requirements increases with an increasing share of energy efficiency lending (area between revenue and transaction cost lines). The optimal portfolio consists of 50% energy efficiency lending. This is not surprising, because the model assumes that the energy efficiency loans and the conventional loans have the same characteristics, while the default risk of both project types is not perfectly correlated.

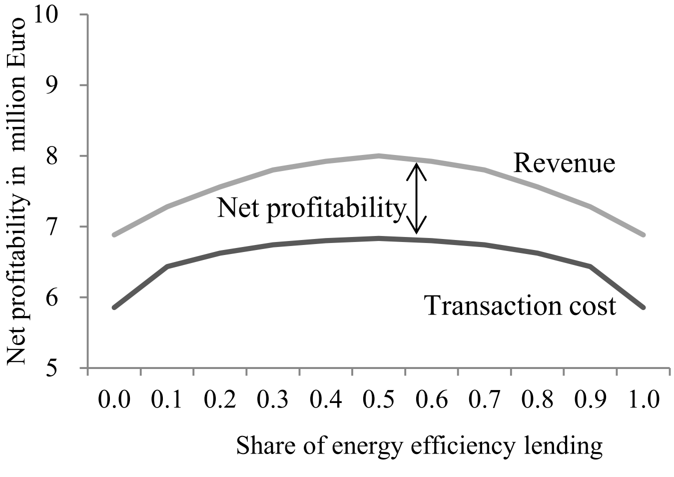

Figure 5.2: Transaction cost and revenue of lending portfolios with equal equity cost

Figure 5.3 shows the probability density function of the project values building the portfolio. The straight lines represent three portfolios from Figure 5.2 where the share of energy efficiency lending is 31%, 50% and 69% respectively. For all three portfolios, the probability of large losses of the lending portfolio that are not covered by equity (area below straight line) corresponds to 0.1%. With an increase in energy efficiency lending to 100 projects, the net profitability increases, because diversification benefits allow the bank to reduce the risk associated with the portfolio and therefore to increase the total lending volume. A further increase in energy efficiency lending yields a lower net profitability. This is because diversification benefits are exploited and the overall lending volume would have to be decreased to meet the capital requirements.

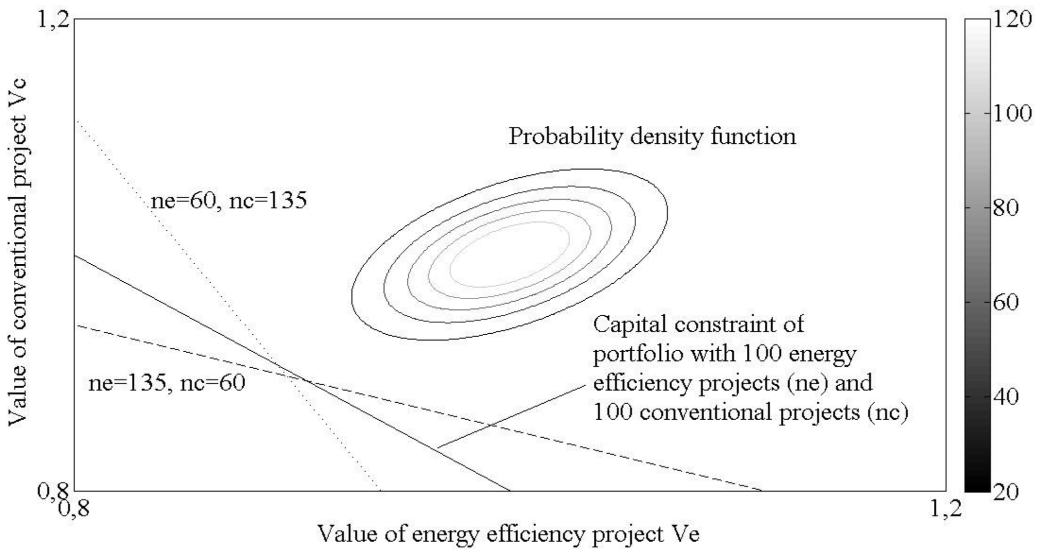

Figure 5.3: Risk diversification of lending portfolios with equal equity cost

The opportunity costs between energy efficiency lending and conventional lending, however, depend on the calibration of the variance and the correlation (Figure 5.4). If the variance of each project type is higher and the correlation between conventional projects and energy efficiency projects is smaller than in the base case (so that capital requirements are just met), the curve of potential portfolios is more curved. In this case an increase in the share of energy efficiency lending from, for example, 20 to 30 projects, requires a lower decrease in conventional lending projects than the base case, but allows for a lower overall number of projects given the capital constraints. The direction of results, however, remains the same.

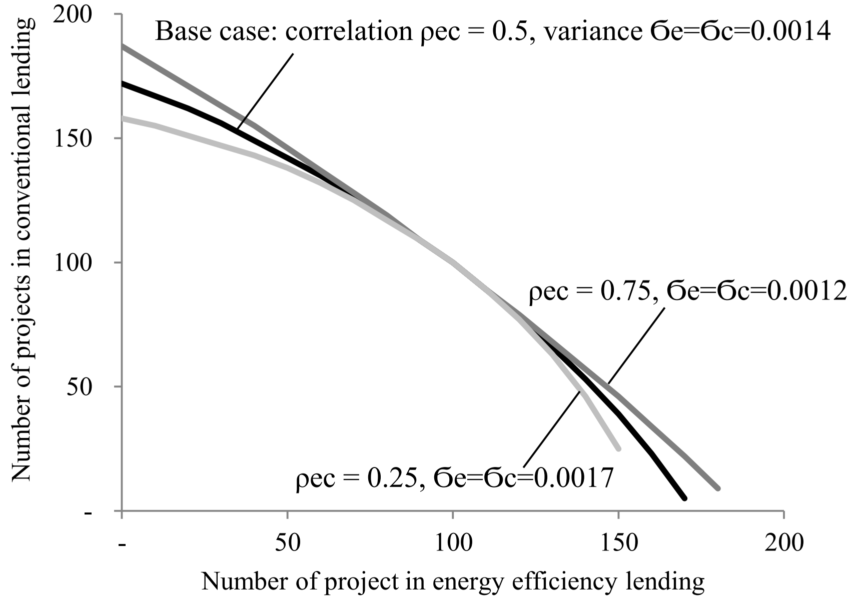

Figure 5.4: Lending portfolios with equal equity cost for various variances and correlations

The model assumes the same characteristics for energy efficiency loans and conventional loans. If banks were to rate energy efficiency loans with a smaller variance (e.g. because energy savings reduce energy price risk exposure), it would be profitable to increase the share of energy efficiency lending above 50% of the overall lending volume. Banks might do so, when the resulting energy savings increase the value of the building or machinery that serves as collateral and therefore decrease the loan to value ratio (see section 3.2). In the interviews, however, it was reported that banks neither account for a lower default risk associated to energy efficiency projects nor do they recognise energy savings as standalone collateral.

5.5 Conclusion

Using Germany, Bulgaria, Poland and Ukraine as case studies, this paper sheds light on commercial banks' incentives related to energy efficiency lending. For this purpose semi-structured interviews were conducted with bankers. Some of the factors as identified in the interviews were modelled to illustrate banks' decision making in this context.

Energy efficiency investments as project type differ from other lending projects in various aspects: information asymmetries and principal agent problems prevent cost-effective energy efficiency investments; energy efficiency lending is a new field of investment where revenue streams derive from energy savings; and assessing these energy savings requires technical expertise.

In Germany, commercial and semi-public banks provide KfW preferential energy efficiency loans and combine these with their classic lending products. This involves some transaction cost, but at the same time allows the banks to gain and bind customers. In addition, some banks initiated their own energy efficiency loans or programmes with reduced interest rates for energy efficiency investments that involve local craftsman. In Bulgaria, Poland and Ukraine, on-lending of EBRD energy efficiency financing differs as commercial banks provide lending at preferential rates only if these are combined with EU grants. Since banks refinance themselves mainly through deposits, longer loan terms and free technical assistance make these loans attractive for commercial banks. They also combine these with their own lending products.

However, so far most banks do not consider energy efficiency specifics in their assessment of creditworthiness or riskiness of the overall lending portfolio. To understand this choice banks' decision-making is modelled. This involves the trade-off between transaction cost for information campaigns or building technical expertise and benefits from diversification and reduced capital requirements. The results demonstrate that energy efficiency lending can actually have benefits for the bank, once initial transaction costs are overcome.

According to these findings, two aspects are important in order to encourage banks to upscale energy efficiency lending: first, the requirement for banks to monetise energy savings in order to account for the benefit of low risk in the lending portfolio and, second, the need for energy efficiency programmes to reach a certain scale so that energy efficiency lending pays off. This in turn may require policy support in order to catalyse market development and to reach the necessary scale. It remains open for further research to explore existing policies, e.g. the Green Deal energy saving loans in the UK where the energy savings are used to pay for the costs of finance.

5.6 Appendix

Matlab code

```
%save as objfun.m
function f = objfun(n)
tef = 4; tcf = 4;
tev = 0.001;
tcv = 0.001;
le = 1; lc = 1;
re = 0.05; rc = 0.05;
ne = n(1);
nc = n(2);
t = tef+sqrt(tev*ne*le)+tcf+sqrt(tcv*nc*lc); t
rev = ne*re*le+nc*rc*lc;
f = rev-t;f=-f; rev

%save as constraint.m
function [c,ceq]=constraint(n)
ue = 1; uc = 1;
vare = 0.0014; varc = 0.0014;
Ve_Min = ue-6*sqrt(vare);
Ve_Max = ue+6*sqrt(vare);
Ve_step = 0.001;
Ve = Ve_Min:Ve_step:Ve_Max;
Vc_Min = uc-6*sqrt(varc);
Vc_Max = uc+6*sqrt(varc);
Vc_step = 0.001;
Vc = Vc_Min:Vc_step:Vc_Max;
rho = 0.496;
alfa = 0.001;
E = 20;
le = 1; lc = 1;
ne = n(1);
nc = n(2);
sum = 0; % Integration in whole area
sum1 = 0;   % Integration in area left of constraint
for i=1: length(Ve)
   for j=1:length(Vc)
      g(i,j) = 1/(2*pi*sqrt(vare)*sqrt(varc)*sqrt(1-rho^2))*exp(-1/(2*(1-rho^2))*...
      ((Ve(i)-ue)^2/vare-2*rho*(Ve(i)-ue)/sqrt(vare)*(Vc(j)-uc)/sqrt(varc)+(Vc(j)-uc)^2/varc));
      sum = sum+g(i,j)*Ve_step*Vc_step;
      if (Vc(j)<(-ne*Ve(i)+ne*le+nc*lc-E)/nc)
         sum1 = sum1+g(i,j)*Ve_step*Vc_step;
      end
   end
end
sum1
c = sum1-alfa; ceq = [];
 %in command window:
n0 = [100;100];lb =[100;100]; ub =[100;100];[n,profit]=fmincon('objfunS1',n0,[],[],[],[],lb,ub,'constraintS1')
```

6. Conclusions and perspectives

This thesis examines the role of specific policy instruments in providing financial incentives for low carbon investments in order to achieve desired emission reductions. In so doing, it sheds light on various types of actors, their requirements and the role the selected policy instruments play in encouraging a shift of investment toward low carbon technologies. Several common insights can be derived from these specific analyses:

Low carbon investment requires a shift of investment from carbon intensive to low carbon technologies

Low carbon transformation means attracting investment away from carbon intensive technologies and, at the same time, increasing profitability and reducing risks for low carbon options. Investments in renewable energy and energy efficiency are often capital intensive with high upfront costs, but low variable costs. Furthermore, they can involve new technologies, new firms, new business models and new business opportunities.

This thesis considers different fields requiring a shift toward low carbon options: The power and industry sectors covered under the European Emission Trading System (EU ETS) account for almost half of Europe's territorial CO_2 emissions. Decarbonising these sectors warrants a switch from carbon intensive technologies, such as coal based power plants or inefficient cement kilns, to low carbon technologies such as renewable energy and energy efficient technologies.

A large share of the total investments in Europe is made by public authorities. The EU budget is the financial vehicle at European level to attain common objectives. The integration of European energy and climate targets in the 2014-2020 EU Regional Development Fund programmes requires a change in regional strategies. This implies that regional policymakers shift funding away from existing priorities in the area of transport or general business support towards new low carbon priorities.

Access to loans for energy efficiency must be provided to unlock many of the energy efficiency potentials. However, commercial banks have not developed corresponding credit lines. Providing capital for energy efficiency investments is a new field of operation for commercial banks. In order to upscale such investments it is necessary to shift from conventional activities to energy efficiency loans.

Incentives and requirements vary with different actors

The incentives and requirements of investing in low carbon options vary according to the various public and private actors, and require detailed analysis rather than general assumptions on preferences.

In the EU ETS, market participants switch from carbon intensive to low carbon options in response to carbon prices. Their investment decisions depend on the current price and their expectation of future prices in relation to their opportunity cost of capital. The analysis of market participants' banking strategies shows that the power sector acquires CO_2 allowances (or contracts on these) as hedges for power forward sale at moderate expected carbon price increases of 5%. In contrast, speculative investors only bank CO_2 allowances if they expect substantial carbon price increases in excess of 10% per year. This demonstrates how important it is to understand what investor type is being targeted when assessing and designing policy instruments.

The analysis of regional policymaking reveals that very different structures are required to create incentives for the implementation of low carbon strategies. Regional policymakers may perceive as risky changes in their existing regional strategies away from known investment fields towards new low carbon investments. Furthermore, they have incentives to use EU money flexibly, in response to market and policy developments during the seven year budget framework, as well as prioritise disbursement of the money over the delivery of policy objectives.

For banks providing loans for energy efficiency investments in the buildings or industry sectors is a new business opportunity involving unknowns and initial transaction costs necessary for the acquisition of the required technical expertise. In order to upscale energy efficiency lending commercial banks need to grow accustomed to energy efficient technologies and project types, to initiate cooperation with the energy service market, and to raise awareness among clients. The modelling of banks' financial incentives demonstrates one key challenge – energy efficiency lending is only economically viable once a certain scale is reached.

Policy framework needs to address different actors

To shift investments towards a low carbon development, the policy framework has to be tailored to address the varied needs of different actors. This thesis focuses on how tailored policy intervention can provide financial incentives for these actors.

The EU ETS seeks to guide project investments, by increasing the costs of carbon intensive technologies and thus creating a competitive advantage for low carbon options, as well as aiding the strategic choices made by firms through enhancing the credibility of future emission reduction targets. The effectiveness of this instrument in achieving either of these objectives has been reduced by a large surplus that has not found investors who value the allowances sufficiently high to maintain previous carbon price levels. This thesis quantifies the surplus allowances that have accumulated and finds that hedging by the power and industry sectors has absorbed the majority of these surplus allowances. Additional surplus allowances must be banked by speculative investors who require higher rates of return. Therefore, it is necessary for the fixing of the EU ETS that all the various actors who invest in CO_2 allowances and their associated risk and return requirements are considered. The proposed EU ETS market stability reserve reflects this aspect: The European Commission foresees adjusting supply if the surplus exceeds or falls below the hedging corridor of the European power sector (EU, 2014). Further analysis on the dynamics of the hedging demand by the power sector over longer time periods is needed to allow for the careful design of a robust stability reserve. Lessons can also be drawn from flexibility mechanisms in the emission trading schemes in California, the Northeast and Mid-Atlantic states in the United States, and Australia.

The amount of EU funding policymakers have at their disposal is not trivial. One fifth of the 2014-2020 EU budget is attributed to European energy and climate targets. This raises the question of how policy design can ensure that regional policymakers adjust their strategies and dedicate this public money to low carbon options. Experience gleaned from the 2007-2013 period indicates that the allocation under the Regional Development Fund can create incentives to counteract risk aversion and inertia toward new investment fields, insofar as it requires policymakers to define their so-called priority axes in line with EU climate and energy objectives, if they wish to qualify for access to the budget. The associated review process can balance the incentives of regional policymakers to use EU money flexibly and to reflect energy and climate targets in project selection.

The EU Energy Efficiency Directive requires member states to develop long term strategies in order to aid investment decisions of the buildings sector and financial institutions in building renovations (EU, 2012b). This thesis discusses the role public banks can play, through their lending programmes, in helping commercial banks to achieve scale of energy efficiency lending, for example by catalysing the market development with technical assistance or preferential loans. Analysis of the implementation of the EU Energy Efficiency Directive through National Energy Efficiency Action Plans can provide further insights into effective approaches to leverage private investment.

To summarise, the selected policy instruments outlined above play a complementary role in bringing the incentives of the different actor groups into line with European climate policy objectives. This thesis aims to contribute detailed analysis of these actors by focusing on financial incentives to promote the attractiveness of low carbon options.

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