TEXTE
116/2019

Modellversuch Flächenzertifikatehandel

Realitätsnahes Planspiel zur Erprobung eines überregionalen Handelssystems mit Flächenausweisungszertifikaten für eine begrenzte Anzahl ausgewählter Kommunen

Abschlussbericht - Anhang VI

Für Mensch & Umwelt

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Anhang VI: Laborexperiment (Anlagenband)

Das an der Universität Göttingen durchgeführte *Laborexperiment* als Teil des *Kontrollierten Feldexperiments* (Kapitel 7) untersuchte ein mögliches Flächenhandelssystem unter kontrollierten Laborbedingungen. Das *Laborexperiment* bestand aus fünf Einzelexperimenten, die zum Teil während der Projektlaufzeit des Modellversuchs in referierten Journals veröffentlicht wurden. Dieser Anhang dokumentiert die Veröffentlichungen zu den einzelnen Experimenten in ihren Workingpaper-Versionen.

- Anhang 6.1: Workingpaper Nr. 1: Die Effizienz von Zuteilungsmechanismen bei Flächenzertifikaten zwischen Versteigerung und Grandfathering – experimentelle Evidenz
- Anhang 6.2: Workingpaper Nr. 2: Experimental evidence on the resilience of a cap & trade system for land use in Germany
- Anhang 6.3: Workingpaper Nr. 3: The political economy of certificates for land use in Germany – Experimental Evidence
- Anhang 6.4: Workingpaper Nr. 4: Tradable development rights under uncertainty: an experimental approach
- Anhang 6.5: Workingpaper Nr. 5: The role of communication on an experimental market for tradable development rights

Workingpaper Nr. 1

Die Effizienz von Zuteilungsmechanismen bei Flächenzertifikaten zwischen Versteigerung und Grandfathering – experimentelle Evidenz

von

Dr. Lukas Meub, Dr. Till Proeger, Prof. Dr. Kilian Bizer und Dr. Ralph Henger

Center for European, Governance and Economic Development Research
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DIE EFFIZIENZ VON ZUTEILUNGSMECHANISMEN BEI FLÄCHENZERTIFIKATEN ZWISCHEN VERSTEIGERUNG UND GRANDFATHERING – EXPERIMENTELLE EVIDENZ

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Die Effizienz von Zuteilungsmechanismen bei Flächenzertifikaten zwischen Versteigerung und Grandfathering – experimentelle Evidenz

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Zusammenfassung: Die Einführung handelbarer Flächenzertifikate wird als Regulierungsinstrument zur Reduktion des Flächenverbrauchs in Deutschland diskutiert. Bislang fehlen jedoch empirische Studien zur Untersuchung der Wohlfahrts- und Umverteilungswirkung eines solchen cap & trade Systems. Insbesondere die Frage nach der Effizienz verschiedener Mechanismen der Primärallokation von Zertifikaten ist politisch relevant, aber bisher nicht untersucht. Die vorliegende Studie analysiert daher anhand eines ökonomischen Laborexperiments, das ein Zertifikatsystem zur Flächenverbrauchsreduktion simuliert, die Auswirkungen von drei Primärallokationsmechanismen: einer vollständigen Gratiszuteilung, einer ausschließlichen Versteigerung und einer hälftigen Aufteilung von Gratiszuteilung und Versteigerung. Es zeigt sich, dass ein Auktionsmechanismus die Effizienz und Stabilität des Zertifikatsystems senkt. Zertifikatpreise weisen eine höhere Volatilität auf und es bestehen stärker als durch die Theorie zu erwartende Umverteilungseffekte zu Gunsten des Auktionators. Persistente Preisunterschiede zwischen Auktion und innerkommunalem Handel verhindern eine effiziente Allokation der Zertifikate. Während das Zertifikatsystem insgesamt bei einer Gratiszuteilung einen hohen Effizienzgrad erreicht, führt ein Auktionsmechanismus zu Ineffizienzen, Unsicherheit und starken Umverteilungswirkungen. Aus wirtschaftspolitischer Sicht unterstützen diese Ergebnisse eine Gratis-Zuteilung innerhalb eines Systems handelbarer Flächenzertifikate.

Keywords: Flächenverbrauch, Grandfathering, handelbare Flächenzertifikate, ökonomisches Experiment, Versteigerung, Zuteilungsmechanismen

I. Einleitung

In Fortschreibung der nationalen Nachhaltigkeitsstrategie (Bundesregierung 2002) formuliert auch der aktuelle Koalitionsvertrag von 2013 das Ziel einer Reduktion des deutschlandweiten Flächenverbrauchs auf 30 ha pro Tag (Koalitionsvertrag 2013; Jakubowski/Zarth 2003). Die ursprüngliche bundesstaatliche Zielsetzung wird somit aufrechterhalten, ungeachtet der weiterhin hohen Ausweisung von Siedlungs- und Verkehrsflächen, die in den Jahren 2009-2012 etwa 74 ha pro Tag betrug (Statistisches Bundesamt 2013). Zur Erfüllung des Regulierungsziels wurden in der Vergangenheit eine Vielzahl potentieller Maßnahmen vorgebracht, etwa eine striktere regulatorische Kontrolle auf allen staatlichen Ebenen oder eine direkte Besteuerung von Flächenverbrauch (Bizer et al. 1998; Henger/Schröter-Schlaack/Ulrich et al. 2010; Bovet/Koeck/Henger et al. 2011). Im Gegensatz zu diesen ordnungsrechtlich geprägten Ansätzen steht die ursprünglich von umweltökonomischer Seite vorgeschlagene Einrichtung eines Systems handelbarer Flächenzertifikate, dessen weitere Untersuchung in Modellstudien ebenfalls im jüngsten Koalitionsvertrag als Ziel genannt wird.

Der wissenschaftliche Diskurs zur generellen Umsetzbarkeit und Effizienz von cap & trade für die Fläche ist durch die Diskussion um CO_2-Zertifikate motiviert und leitet hieraus eine Reihe potentieller Vorteile ab. Diese Vorteile ergeben sich aus den theoretischen Eigenschaften des cap & trade Systems: Im Zentrum steht dabei die effiziente, landesweite Umverteilung von Zertifikaten hin zu den ökonomisch rentabelsten Flächenausweisungsprojekten bei minimalen Transaktionskosten. Eine Mengensteuerung bei variablen Preisen ermöglicht so die präzise Erfüllung des Regulierungsziels. Darüber hinaus wird erwartet, dass Flächenzertifikate Anreize zur effizienteren Landnutzung und Innenentwicklung geben und sich die Aufmerksamkeit für die Umweltproblematik der

Landnutzung bei Kommunen insgesamt erhöht.[1] Um diese aus der Theorie hergeleiteten Vorteile empirisch zu untersuchen, wurden bislang zwei Feldexperimente mit kommunalen Akteuren durchgeführt, die eine realitätsnahe Simulation eines Systems handelbarer Flächenzertifikate erlauben, wobei dessen grundsätzliche Funktionsfähigkeit betont wurde (Ostertag/Schleich/Ehrhart et al. 2010; Henger 2011; Bizer/Bovet/Henger et al. 2012; Henger 2013; Bovet/Bizer/Henger et al. 2013).

In diesen Feldexperimenten konnte jedoch aus Gründen der praktischen Umsetzbarkeit keine Bewertung des Mechanismus der Primärallokation von Flächenzertifikaten vorgenommen werden. Empirisch fundierte Aussagen über die Effizienz- und Verteilungswirkungen bei einer Versteigerung im Vergleich zu einer Gratiszuteilung sind somit bislang nicht möglich. Dies ist insofern problematisch, als die Frage der Primärallokation im Mittelpunkt des Interesses aller Akteure - und damit der politischen Diskussion - steht. Hierbei streben die Betroffenen nach einer möglichst langfristigen Gratis-Zuteilung (Grandfathering), die umweltökonomisch argumentierenden Regulierer hingegen nach der frühzeitigen Auktion eines möglichst hohen Anteils an Zertifikaten (Goeree/Palmer/Holt et al. 2010). Die folgende Untersuchung liefert eine empirisch-experimentelle Grundlage zur Beantwortung der Frage nach der Effizienz- und Verteilungswirkung des gewählten Primärallokationsmechanismus.

Während bislang nur wenige empirische Untersuchungen zu Implementationsalternativen von handelbaren Flächenzertifikaten vorliegen, besteht eine ausführliche umwelt- und experimentalökonomische Literatur zu verschiedenen Varianten von Märkten für SO_2- und

[1] Eine Vielzahl von Studien diskutiert die verschiedenen Aspekte und potentiellen Vor- und Nachteile von Flächenzertifikaten (Köck/Bizer/Hansjürgens et al. 2008). Für einen Überblick sei an dieser Stelle auf die Dissertationen von Schröter-Schlaak (2013), Henger (2010) und Schmalholz (2005) verwiesen, welche die ökonomischen Kernargumente entwickeln und umfassend darstellen. Weitere relevante Beiträge sind etwa Bizer 1996; Hansjürgens/Schröter-Schlaack (2004); Hansjürgens/Schröter-Schlaack (2008) und Henger/Bizer (2010).

CO_2-Emissionszertifikate.[2] Die politische Diskussion und Einführung von Emissionshandelssystemen wurde von wissenschaftlicher Seite auch durch ökonomische Laborexperimenten begleitet, die – z.B. im Kontext des CO_2-Zertifikatehandels – verschiedene Teilaspekte der Märkte beleuchtet haben.[3] Auch für den im Folgenden untersuchten Kernaspekt der ökonomischen Effizienz verschiedener Primärallokationsmechanismen sind Laborexperimente durchgeführt worden. Die Vorhersage ökonomischer Theorie, gegeben den üblichen Annahmen wie perfekt rationalen Akteuren, ist hierbei die Wohlfahrtsneutralität der konkreten Methode der Primärallokation. Im Gegensatz dazu legen experimentalökonomische Studien nahe, dass die spezifische Methode der Primärallokation durchaus Einfluss auf die Marktergebnisse besitzt. Dies wurde zuletzt in den Experimenten von Grimm/Ilieva (2013), Goeree/Palmer/Holt et al. (2010), sowie Benz/Erhard (2007) gezeigt. Hierbei resultiert eine leicht höhere Leistungsfähigkeit der Märkte, wenn statt einer Gratisallokation von Zertifikaten (Grandfathering) eine vollständige Versteigerung implementiert wird, wobei Goeree/Palmer/Holt et al. (2010) darauf hinweisen, dass beide institutionellen Varianten keine vollständige Effizienz innerhalb des Marktes erzielen. In jedem Fall wird durch diese Untersuchungen die Diskrepanz zwischen theoretischen Verhaltensvorhersagen und tatsächlich eingetretenem Verhalten der Spieler deutlich.

Zwar können diese Ergebnisse als Ausgangspunkt für die Diskussion über die Ausgestaltung von Zertifikatsystemen im Kontext des Flächenhandels dienen, jedoch hindert deren Fokussierung auf die Struktur der Märkte für Emissionsrechte die unmittelbare

[2] Für einen Einstieg in die Literatur vgl. die Übersichtspapiere von Convery (2009); Martin/Muûls/Wagner (2012) und Wrake/Burtraw/Löfgren et al. (2012).

[3] Hierzu zählen zentral Aspekte wie Marktmacht (Cason/Gangadharan/Duke 2003), Preissetzungsstrategien und Fixpreise (Burtraw/Goeree/Holt et al. 2011; Wrake/Myers/Burtraw et al. 2010; Shobe/Palmer/Myers et al. 2009 und Wrake/Myers/Mandell et al. 2008), oder auch die Folgen von Spekulation auf Zertifikatsmärkten (Burtraw/Goeree/Holt et al. 2009 und Mougeot/Naegelen/Pelloux et al. 2011).

Anwendbarkeit für das Gut „Fläche". Hierbei sind insbesondere die in vielerlei Hinsicht geringere Flexibilität kommunaler Akteure im Vergleich zu gewinnmaximierenden Unternehmen und die Rolle der Wahlmöglichkeit zwischen Innen- und Außenentwicklung für das Regulierungsziel zu nennen. Insofern sind spezifische ökonomische Experimente notwendig, die den derzeitigen Planungsstand für eine mögliche Anwendung von Flächenzertifikaten nachbilden und damit Aussagen über die Effizienz, Umverteilungs- und Wohlfahrtswirkung verschiedener Primärallokationsmechanismen zulassen.

Die Methodik ökonomischer Laborexperimente bietet dabei eine Reihe von Vorteilen. Sie ermöglicht kontrafaktische Vergleiche verschiedener wirtschaftspolitischer Rahmensetzungen, die einer herkömmlichen empirischen Analyse im existierenden institutionellen Rahmen per se nicht zugänglich sind. Zwar weisen Laborexperimente mit studentischen Probanden einen hohen Abstraktionsgrad und damit eine geringere externe Validität als Feldexperimente auf, wodurch bei der unmittelbaren Übertragung auf tatsächlich handelnde Akteure und daraus abgeleitete wirtschaftspolitische Empfehlungen Vorsicht geboten ist. Dennoch ermöglicht diese Form der empirischen Wirtschaftsforschung Tendenzaussagen über die Wirkung verschiedener institutioneller Regelungen. Diese Aussagen sind für evidenzbasierte wirtschaftspolitische Entscheidungen bei ansonsten empirisch nicht zugänglichen Fragen hilfreich. In diesem Sinne stellt das vorliegende Experiment kontrafaktische, empirische Aussagen für die Wirkung verschiedener Primärallokationsmechanismen bereit.

Das Experiment bildet dafür möglichst präzise den bisherigen Stand der wissenschaftlichen Diskussion ab.[4] Jeder Proband repräsentiert einen kommunalen Entscheidungsträger, wobei Kommunen durch die Realisation von Flächenausweisungen im Spielverlauf Einkommen generieren können. Sechs dieser Spieler agieren auf einem gemeinsamen Zertifikatmarkt. Die Durchführung von Flächen verbrauchenden Projekten ist durch die Verfügbarkeit von

[4] Für einen Überblick zur aktuellen Diskussion vgl. www.flaechenhandel.de.

Zertifikaten exogen begrenzt. In drei verschiedenen Varianten des Spiels (Treatments) wird der Modus der Primärallokation variiert: im ersten Treatment (*Zuteilung*) werden alle Zertifikate nach einem festen Schlüssel kostenlos an die Spieler ausgegeben; im zweiten Treatment (*Mischform*) werden je 50% der Zertifikate versteigert und 50% gratis zugeteilt; im dritten Treatment (*Versteigerung*) wiederum werden alle Zertifikate versteigert. Das Spiel läuft über mehrere Runden mit jeweils drei Phasen. In der ersten Phase wird die treatmentspezifische Primärallokation der Zertifikate vorgenommen; in der zweiten Phase können die Spieler auf einem Sekundärmarkt Zertifikate handeln; in der dritten Phase können alle Spieler je ein „Projekt“ durchführen, das eine Flächenausweisung simuliert, sofern sie zuvor genügend Zertifikate akkumuliert haben. Die Auszahlung der Spieler ergibt sich schließlich aus der Anzahl und Rentabilität der im gesamten Spiel durchgeführten Projekte und den potentiellen Gewinnen aus dem Zertifikathandel.

Dieser experimentelle Rahmen ermöglicht einen ceteris paribus Vergleich der Primärallokationsmechanismen und damit die Ableitung wirtschaftspolitischer Implikationen, was in der vorliegenden Untersuchung wie folgt dargestellt wird: Abschnitt zwei präsentiert detailliert das experimentelle Design und führt dabei den Rahmen des individuell optimalen Verhaltens als Vergleichsmaßstab ein. Im dritten Abschnitt werden die Ergebnisse beschrieben, Abschnitt vier nimmt eine Schlussbetrachtung mit Ergebniszusammenfassung vor.

2. Experimentelles Design

Das experimentelle Design der vorliegenden Studie wird in fünf Abschnitten dargestellt. Zunächst soll der generelle Ablauf des Spiels geschildert werden; daraufhin die Details der Spieler- und Projekttypen, welche die Probanden einnehmen bzw. umsetzen. Drittens werden die Auszahlungsbedingungen der Spieler beschrieben und viertens das theoretisch optimale

Verhalten als Benchmark für die folgende Auswertung hergeleitet. Abschnitt fünf gibt Informationen zur Experimentdurchführung.

Spielablauf

Der Grundaufbau des Spiels ähnelt den bisher durchgeführten Feldexperimenten (Ostertag/Schleich/Ehrhart et al. 2010; Henger, 2011) und verwendet den gleichen Grundaufbau wie ein anderes aktuelles Laborexperiment der Autoren (Bizer/Henger/Meub et al. 2014), wobei das zweite Treatment *Mischform* in dieser Studie ebenfalls als Kontrolltreatment verwendet wird.

In 15 Spielrunden mit je drei Phasen simulieren Studierende das Verhalten je einer Kommune, die Flächennutzungszertifikate akkumuliert und mit diesen Projekte realisiert. Jeder Proband spielt nur eines der drei Treatments. Je sechs Spieler werden zufällig einer Gruppe zugeordnet, die so gemeinsam einen Zertifikatmarkt bilden. Wie in ökonomischen Experimenten üblich, wird eine neutrale Wortwahl verwendet, die Framing-Effekte ausschließt und somit für Probanden keinen Rückschluss auf Kommunen, Flächenhandel, Umweltschutz o.ä. zulässt.[5] In den drei Phasen jeder Runde werden die Primärallokation, der Handel auf dem Sekundärmarkt und den Einsatz der Zertifikate zur Projektrealisierung durch die Kommune abgebildet.

In der ersten Phase findet die Primärallokation von Zertifikaten statt, die gleichzeitig die Treatmentvariation darstellt. Im Treatment *Zuteilung* werden insgesamt 24 Zertifikate pro Runde gratis an die Spieler ausgegeben; im Treatment *Mischform* werden 12 Zertifikate versteigert und 12 Zertifikate gratis zugeteilt; im Treatment *Versteigerung* wiederum werden alle 24 Zertifikate versteigert. Als Versteigerungsmechanismus wird eine verdeckte

[5] Die Instruktionen (Spielregeln für die Probanden) des Spiels werden als Online-Material bereitgestellt.

Einheitspreisauktion implementiert.[6] Der Auktionator simuliert im Spiel die regulierende bundesstaatliche Ebene und erzielt durch die Versteigerungen Erlöse, die für die Spieler (Kommunen) direkt ausgabenwirksam werden. Die einzige Unterscheidung zwischen den drei Treatments ist damit die Variation des Primärallokationsmechanismus in der ersten Spielphase; alle andere Bedingungen des Spiels bleiben identisch (ceteris paribus Bedingung). In der zweiten Phase können die Spieler zwei Minuten lang ihre Zertifikate frei per zweiseitiger Auktion ohne Preis- oder Mengenbegrenzungen handeln. Auf diesem Sekundärmarkt können die Spieler durch Verkäufe Einnahmen erzielen oder zusätzliche Zertifikate für die Umsetzung von Projekten von anderen Spielern erwerben.

In der dritten Phase können die Projekte umgesetzt werden. Spieler generieren so Einkommen je nach Höhe der Projektwerte. Jeder Spieler kann pro Runde nur ein Projekt umsetzen. Nicht genutzte Zertifikate können über die 15 Runden angespart werden, verfallen jedoch nach der letzten Runde ohne eine Ausgleichszahlung.

Spieler- und Projekttypen

Wie beschrieben werden alle Spieler zufällig einer Gruppe aus sechs Spielern zugeordnet. Innerhalb dieser Gruppen wird wiederum zufällig jedem Spieler ein spezifischer Spielertyp zugeordnet, wobei die Spielertypen verschieden große Kommunen simulieren. Jeder Spielertyp hat für das gesamte Spiel eine Ausstattung mit 45 Projekten zur Verfügung.

Es gibt zwei Projekttypen, die mit „Typ A“ und „Typ B“ bezeichnet werden. Für die Umsetzung eines Typ A Projekts, das Außenentwicklungsprojekte mit hohem Flächenverbrauch repräsentiert, werden einheitlich acht Zertifikate benötigt. Typ B Projekte

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[6] Bei einer Einheitspreisauktion geben die Bieter je einen Preis und die gewünschte Menge an. Alle Gebote werden dann nach ihren Preisen geordnet und die Zertifikate entsprechend zugeteilt, wobei der Preis des letzten bedienten Gebots den Preis für alle Bieter bestimmt.

benötigen keine Zertifikate, was ein Innenentwicklungsprojekt simuliert.[7] Projekte des Typs A generieren für den durchführenden Spieler eine Auszahlung von 0 bis 100 ECU (Experimentelle Währungseinheiten) in Schritten zu 20 ECU. Projekte des Typs B erzielen einheitlich 10 ECU.

Projekt	**Nummer**	1	2	3	4	5	6	7	
	Wert	100	80	60	40	20	0	10	
	Typ	A	A	A	A	A	A	B	
	Zertifikate	8	8	8	8	8	8	0	
Spielertyp									**Gesamt**
	1- sehr groß	10	8	6	4	2	0	15	**45**
	2- groß	8	10	6	4	2	0	15	**45**
	3- mittel	6	8	10	4	2	0	15	**45**
	4- klein	4	6	8	10	2	0	15	**45**
	5- klein	2	4	6	8	10	0	15	**45**
	6- klein	0	2	4	6	8	10	15	**45**
	Gesamt	**30**	**38**	**40**	**36**	**26**	**10**	**90**	**270**

Tabelle 1. Überblick über Spielertypen und Projekte

Spielertyp	**Anzahl Zertifikate pro Runde (Gesamt)**		
	Zuteilung	*Mischform*	*Versteigerung*
1- sehr groß	8 (120)	4 (60)	0 (0)
2- groß	6 (90)	3 (45)	0 (0)
3- mittel	4 (60)	2 (30)	0 (0)
4- klein	2 (30)	1 (15)	0 (0)
5- klein	2 (30)	1 (15)	0 (0)
6- klein	2 (30)	1 (15)	0 (0)
# Versteigerung	**0 (0)**	**12 (180)**	**24 (360)**
Gesamt	**24 (360)**	**24 (360)**	**24 (360)**

Tabelle 2. Anzahl Zertifikate nach Primärallokationsmechanismus

Die verschiedenen Spielertypen unterscheiden sich also nach ihren verfügbaren Projekten, wobei die „größeren“ Kommunen mehr wertvolle Projekte zur Verfügung haben. Darüber hinaus erhalten die Spielertypen eine unterschiedliche Anzahl kostenloser Zertifikate, was

[7] Die Annahme, dass jedes Außenentwicklungsprojekt die gleiche Fläche verbraucht und daher dieselbe Anzahl an Zertifikaten benötigt, stellt zwar eine erhebliche Vereinfachung der realen Situation dar, ist aber notwendig, um das Spiel für die Probanden verständlich zu halten. Diese Vereinfachung berührt jedoch nicht die Kernaspekte eines Zertifikatsystems oder die Allgemeingültigkeit der Ergebnisse.

eine Allokation nach der Höhe der Einwohnerzahl widerspiegelt. Jeder Spieler kennt seine eigene Projektausstattung und Zuteilungsmenge an kostenlosen Zertifikaten, nicht aber die Projektausstattung der anderen Spieler oder deren Zertifikatzuteilung.

Tabelle 1 zeigt die Spielertypen und die ihnen zur Verfügung stehenden Projekte. Tabelle 2 gibt einen Überblick zu den Zertifikatmengen in Abhängigkeit vom Primärallokationsmechanismus.

Auszahlungsstruktur

Jeder Spieler erhält als Budget eine Anfangsausstattung, um Zertifikate in den Auktionen oder am Sekundärmarkt zu erwerben. Diese ist für alle Spieler gleich, unterscheidet sich aber in Abhängigkeit von der versteigerten Zertifikatmenge. Während unter vollständiger *Zuteilung* die Spieler nur 350 ECU Startguthaben erhalten, ist das Budget in der *Mischform* auf 700 ECU und bei vollständiger *Versteigerung* auf 1400 ECU erhöht. Die unterschiedlichen Anfangsausstattungen kompensieren damit den unterschiedlich hohen Anteil an gratis zugeteilten Zertifikaten. Diese Budgetbeschränkung der Spieler ist bindend, es kann also keine Verschuldung entstehen. Die Budgethöhe ist dabei so gewählt, dass die Spieler potentiell genug Zertifikate zu fairen Preisen ankaufen können, um damit in jeder Runde ein Außenentwicklungsprojekt durchführen zu können (vgl. Abschnitt zum theoretisch optimalen Verhalten). Die Zertifikatkäufe und -verkäufe werden sofort budgetwirksam. Das finale Budget wird den Probanden am Ende des Spiels ausgezahlt. Ebenso werden die Erlöse aus der Projektrealisation am Ende ausgezahlt, um so den Charakter langfristiger Investitionen und verzögerter Einnahmen von Flächenausweisungen abzubilden. Zusätzlich erhalten die Spieler in den Treatments *Zuteilung* und *Mischform* eine verhaltensunabhängige Auszahlung von 5€ bzw. 4€ am Ende des Spiels. Hierdurch wird eine vergleichbare erwartete Auszahlung bezogen auf die zu erwartende Experimentdauer über die Treatments erreicht, ohne dass den Spielern in den Treatments ohne Auktion ein deutlich erhöhtes und damit anreizverzerrendes Budget gewährt werden müsste. Alle Auszahlungen und Preise werden in ECU angegeben, wobei 100 ECU am Ende des Spiels zu 1€ für die Auszahlung der Probanden umgewandelt werden.

Theoretisch optimales Verhalten

Ohne eine restriktive Regulierung würden die Spieler im vorliegenden experimentellen Rahmen ihre 15 profitabelsten Projekte des Typs A umsetzen (vgl. Tabelle 1). Insgesamt würden so pro Gruppe über alle 15 Runden 90 Typ A (Außenentwicklungsprojekte) umgesetzt. Es wird nun angenommen, dass vom Gesetzgeber eine Reduktion des Flächenverbrauchs um 50% angestrebt wird. Daraus ergibt sich eine Restriktion auf drei Typ A Projekte pro Runde, d.h. nur noch die Hälfte der Kommunen wird im Durchschnitt pro Runde Außenentwicklungsprojekte umsetzen können. Insgesamt können in jeder Gruppe nur noch 45 Typ A Projekte und dementsprechend 45 Typ B Projekte umgesetzt werden. Die Allokation der Zertifikate entscheidet dabei sowohl darüber, welche Kommunen Typ A Projekte umsetzen können, als auch wann diese umgesetzt werden. Der vereinfachenden Annahme eines einheitlichen Flächenverbrauchs aller Außenentwicklungsprojekte entsprechend benötigen alle Typ A Projekte acht Zertifikate. Um nun das Regulierungsziel einer Reduktion um die Hälfte auf drei Typ A Projekte pro Runde zu realisieren, wird eine Verknappung der Zertifikate auf 24 Stück pro Runde eingeführt.

Um die Zertifikatpreise im Gleichgewicht abzuleiten, kann zunächst die Zahlungsbereitschaften der Spieler bestimmt werden. Dabei führt die Umsetzung eines Typ A Projekts zu Opportunitätskosten von 10 ECU, also entsprechend der festen Auszahlung für Typ B Projekte, für die keine Zertifikate verbraucht werden würden. Die profitabelsten Typ A Projekte generieren eine Auszahlung von 100 ECU, wofür acht Zertifikate benötigt werden. Die Zahlungsbereitschaft für ein Zertifikat beträgt daher maximal (100-10)/8=11.25 ECU. Insgesamt stehen in jeder Gruppe 30 Projekte von Typ A mit einem Wert von 100 zur Verfügung, was den Spielern allerdings nicht bekannt ist. Daher verhalten sich Spieler optimal im Sinne einer Auszahlungsmaximierung, sofern diese im Primär- und

Sekundärmarkt eine Zahlungsbereitschaft von maximal 11.25 ECU, also dem fairen Wert eines Zertifikats, aufweisen. Höhere durchschnittliche Preise für Zertifikate resultieren zwingend in einem Einkommensrückgang für die Spieler, da der Zahlung von Preisen über diesem fairen Wert keine entsprechenden Erlöse aus Projektumsetzungen entgegenstehen. Der Preis im Marktgleichgewicht sollte nach Umsetzung aller Typ A Projekte mit einem Wert von 100 ECU auf (80-10)/8=8.75 ECU fallen, da nun nur noch Projekte mit einem Wert von 80 ECU umgesetzt werden können. Übersteigen die Marktpreise diese fairen Werte und erwartet man ein auszahlungsmaximierendes Kalkül bei allen anderen Spielern, verkauft ein rationaler Spieler Zertifikate; sinken die Preise darunter, kauft ein rationaler Spieler Zertifikate. Entsprechend richten rationale Spieler ihre Angebote in den Einheitspreisauktionen an diesen fairen Werten aus. Alle Spieler haben alle notwendigen Informationen, um diese fairen Preise abzuleiten. Diese Preise können somit als Benchmark bei der Interpretation der Experimentalergebnisse dienen.

Allerdings ist auf Grund identischer Zahlungsbereitschaften unklar, welche Type A Projekte mit einem Wert von 80 ECU neben den 30 Typ A Projekten mit dem Wert von 100 ECU konkret umgesetzt werden sollten, bzw. welcher Spieler die Projekte umsetzen wird. Es reicht jedoch an dieser Stelle aus, das Ergebnis auf Ebene der Spielertypen anhand der Annahme zu illustrieren, dass Zertifikate bei identischer Zahlungsbereitschaft nach der Kommunengröße zugeteilt werden. Wir nehmen weiterhin an, dass Preise im Primär- und Sekundärmarkt für Zertifikate stets den maximalen Zahlungsbereitschaften entsprechen und kostenlos zugeteilte Zertifikate in der *Mischform* gleichmäßig auf Projekte zu 100 ECU und zu 80 ECU verteilt werden.[8] Unsere Annahme unterstellt also, dass der Auktionator eine perfekte

[8] Spielertyp 1 realisiert zum Beispiel zehn Typ A Projekte mit einem Wert von 100 ECU und fünf mit einem Wert von 80 ECU und erhält insgesamt 60 kostenlose Zertifikate in der *Mischform*. Die vorliegende Berechnung unterstellt dann, dass zwei Drittel der kostenlosen Zertifikate für Projekte mit einem Wert von 100 ECU und ein

Preisdiskriminierung erreicht. So können auch die maximalen Erlöse des Auktionators bestimmt werden. Tabelle 3 zeigt eine detaillierte Darstellung der so abgeleiteten potentiellen Ergebnisse.

Projekt	**Nummer**	1	2	7							
	Wert	100	80	10							
	Typ	A	A	B							
	Zertifikate	8	8	0							
Spieler -typ						**Zertifikate** #kauf(gratis)			**Einkommen**		
					Σ	*Zuteilung*	*Mischform*	*Versteig.*	*Zuteilung*	*Mischform*	*Versteig.*
	1- sehr groß	10	5	0	**15**	0(120)	60(60)	120(0)	1400	775	150
	2- groß	8	5	2	**15**	14(90)	59(45)	104(0)	1075	605	150
	3- mittel	6	5	4	**15**	28(60)	58(30)	88(0)	748	436	150
	4- klein	4	0	11	**15**	2(30)	17(15)	32(0)	489	333	150
	5- klein	2	0	13	**15**	-14(30)	1(15)	16(0)	476	320	150
	6- klein	0	0	15	**15**	-30(0)	-15(15)	0(0)	463	306	150
	Σ	**30**	**15**	**45**	**90**	**0(360)**	**180(180)**	**360(0)**	**4650**	**2775**	**900**
	Auktionator								0	1875	3750
	Σ								**4650**	**4650**	**4650**

Tabelle 3. Theorie zu Wohlfahrt, Zertifikaten und Einkommen nach Primärallokationsmechanismus

Es zeigt sich, dass unabhängig vom Primärallokationsmechanismus 45 Projekte von Typ A und 45 Projekte von Typ B umgesetzt werden sollten. Dies entspricht der effizienten, d.h. wohlfahrtsoptimalen, Erfüllung des Regulierungsziels der Halbierung des Flächenverbrauchs. Lediglich die Einkommensverteilung, also die Verteilung der Erlöse aus den umgesetzten Projekten zwischen Auktionator und Kommunen, wird durch die Primärallokation beeinflusst.

Drittel für Projekte mit dem Wert von 80 ECU genutzt werden. Entsprechend werden von den noch benötigten 60 Zertifikaten 40 zu einem Preis von 11.25 ECU und 20 zu einem Preis von 8.75 ECU angekauft.

Transferzahlungen im Primärmarkt, d.h. erfolgreiche Gebote in der Auktion, haben eine einkommensumverteilende Wirkung zu Gunsten des Auktionators. Bei perfekter Preisdiskriminierung wird das mit Hilfe der auktionierten Zertifikate geschaffene Einkommen durch Projektrealisierungen vollständig an den Auktionator umverteilt. Die Einkommensverteilung zwischen den Spielertypen ist bestimmt durch die zur Verfügung stehenden Projekte und die Anzahl der zugeteilten Zertifikate. Transferzahlungen im Sekundärmarkt bewirken eine Einkommensumverteilung innerhalb der Kommunen, da diese als Käufer und Verkäufer auftreten und annahmegemäß keine Transaktionskosten bestehen. Somit ergibt sich insgesamt, dass Ineffizienzen nur durch die Umsetzung von Projekten mit inferiorem Wert entstehen können. In diesem Fall würden Zertifikate nicht optimal eingesetzt und es würde eine Fehlallokation vorliegen.

Die Betrachtungen in diesem Abschnitt folgen der Annahme, dass Spieler gewinnmaximierend handeln und dies auch von den anderen Spielern ihrer Gruppe erwarten. Hierbei wäre eine perfekte ex-ante Evaluation des gesamten Spielverlaufs durch die Spieler erforderlich, was natürlich eine möglicherweise unrealistische Annahme ist. Zudem wurde nicht auf mögliche Spekulationsmotive, Arbitrage oder Pfadabhängigkeiten im Spiel abgestellt. Die präsentierten theoretischen Überlegungen können und sollen also nicht alle Eventualitäten und individuellen Handlungsmotive abdecken. Dennoch bilden sie eine objektive Benchmark, an welcher die Ergebnisse der experimentellen Durchführung eingeordnet werden können und durch die systematische Abweichungen vom optimalen Verhalten identifiziert und Ineffizienzen quantifiziert werden können.

Experimentdurchführung

Treatment	**Zuteilung**	**Versteigerung**	**Anzahl Teilnehmer**	**Anzahl Gruppen**
Zuteilung	100%	0%	42	7
Mischform	50%	50%	48	8
Versteigerung	0%	100%	42	7
Gesamt			**132**	**22**

Tabelle 4. Zusammenfassung der Treatments und Probandenanzahl

Tabelle 4 gibt einen Überblick der Treatments, der Variation des Primärallokationsmechanismus und die Anzahl der Probanden. Die Experimentdurchführung fand in zehn Sessions im Oktober und Dezember 2014 im Experimentallabor der Universität Göttingen (GLOBE) statt. Die Probanden wurden mit dem Programm ORSEE rekrutiert (Greiner 2004) und das Spiel mit der Software z-Tree programmiert (Fischbacher 2007). Jeder Proband durfte nur einmal teilnehmen; das Spielverständnis aller Probanden wurde durch verpflichtende Kontrollfragen zu Beginn des Spiels geprüft. Die Sessions dauerten rund 80 Minuten; jeder Proband verdiente im Durchschnitt 14.42€. Die Probanden rekrutieren sich aus verschiedenen Studienfächern (37% davon Wirtschaftswissenschaftler), waren im Durchschnitt 24.5 Jahre alt, bei einem Frauenanteil von 52%.

3. Ergebnisse

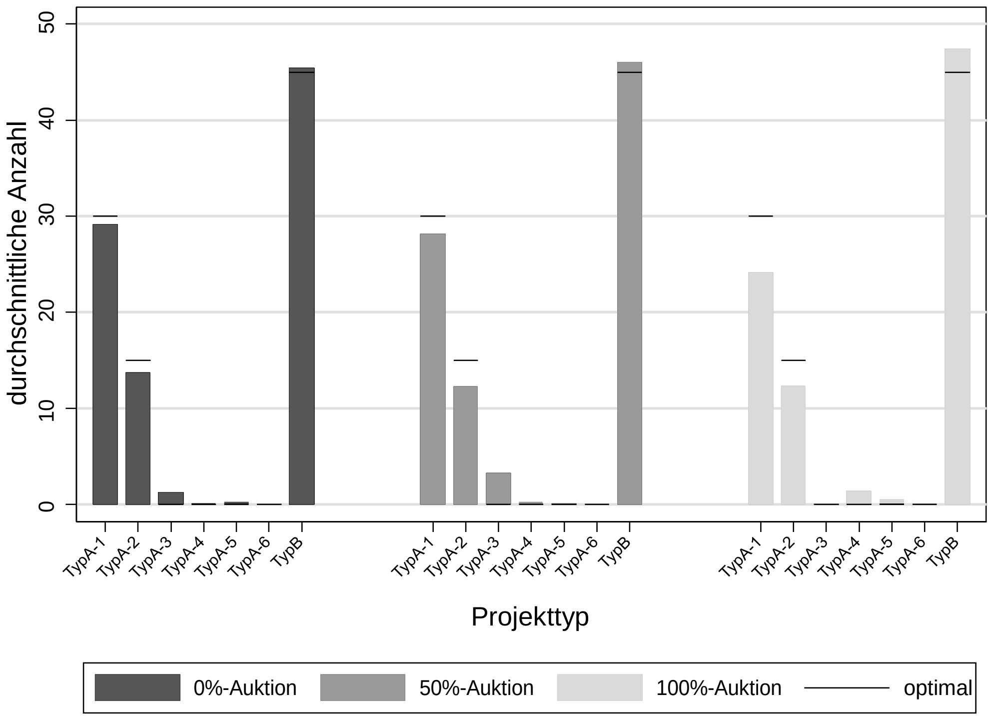
Im Folgenden werden die Experimentalergebnisse hinsichtlich der Wirkung der verschiedenen Primärallokationsmechanismen auf die zentralen ökonomischen Indikatoren Wohlfahrt, Preisentwicklung und Einkommensverteilung analysiert.

Wohlfahrt und Effizienz

Zunächst soll untersucht werden, inwiefern ein System handelbarer Flächenausweisungzertifikate eine effiziente Umsetzung des Regulierungsziels bewirkt und welche Bedeutung dabei dem Primärallokationsmechanismus zukommt.

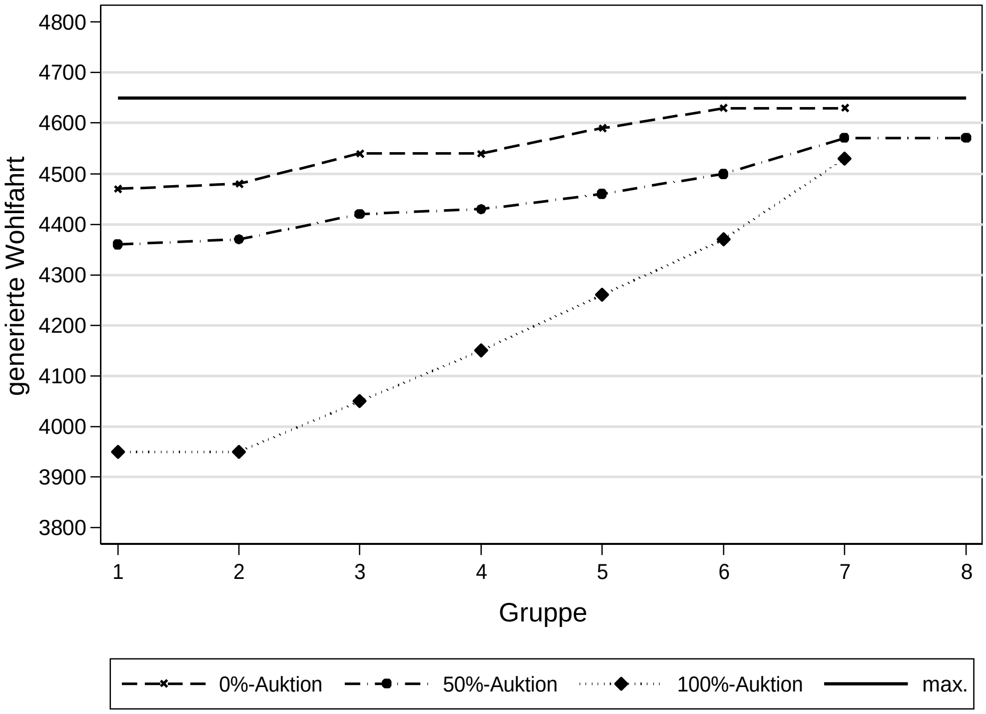
Die Spieler im Experiment lassen sich als Kommunen interpretieren, die Einkommen durch die Umsetzung von ggf. flächenverbrauchenden Projekten unter Einsatz von zuvor akkumulierten Zertifikaten generieren. Der Ankauf dieser Zertifikate geschieht im Rahmen der Auktionen im Primärmarkt oder am Sekundärmarkt, in welchem Zertifikate frei gehandelt werden. Hierbei entstehen Einkommensumverteilungen zwischen den Kommunen oder von den Kommunen zum Auktionator, die jedoch nicht wohlfahrtswirksam sind. Ineffizienzen können daher lediglich durch die Umsetzung von Projekten mit inferiorem Wert entstehen, also dem Einsatz von Zertifikaten für ein ertragsschwächeres Projekt, obwohl ein ertragsstärkeres möglich wäre. Abbildung 1 zeigt die im Durchschnitt umgesetzten Projekte, aggregiert über Gruppen für die drei Primärallokationsmechanismen. Zudem werden die oben hergeleiteten Optimalwerte angezeigt (30 Typ A Projekte mit einem Wert von 100 ECU, 15 im Wert von 80 ECU und 45 Typ B Projekte).

Abbildung 1. Projektrealisierungen nach Primärallokationsmechanismus



Es wird deutlich, dass für den Fall vollständig kostenloser Zertifikatzuteilung eine hohe Effizienz erzielt wird. Die durchschnittliche Anzahl umgesetzter Projekte erreicht nahezu die theoretisch optimalen Werte, entsprechend werden Zertifikate für die Realisierung der wertvollsten Außenentwicklungsprojekte verwendet. Dagegen wird eine optimale Allokation bei einer vollständigen Auktion deutlich verfehlt. Die gemischte Primärallokation stellt ein mittleres Niveau in Bezug auf die Effizienz dar. Um einen differenzierteren Einblick zu erhalten, zeigt Abbildung 2 die durch umgesetzte Projekte geschaffene Wohlfahrt für jede einzelne Gruppe in aufsteigender Rangordnung ab.

Abbildung 2. Wohlfahrt für jede Gruppe nach Primärallokationsmechanismus



Wie die aggregierte Betrachtung gezeigt hat, erreichen Gruppen unter vollständig kostenloser Zertifikatzuteilung nahezu das maximale Wohlfahrtsniveau von 4650 ECU (siehe Tabelle 3), die schwächste Gruppe erzielt immer noch 96% dieses Werts. Erfolgt eine hälftige Versteigerung, sinkt die geschaffene Wohlfahrt auf ein signifikant niedrigeres Niveau (Wilcoxon-Rank-Sum Test; n=15, z=2.089 und p<0.0367), wobei der Durchschnitt über die Gruppen um 2% von 4554 ECU auf 4460 ECU sinkt.[9] Erfolgt eine vollständige Versteigerung, ist nicht nur ein klarer Niveaueffekt festzustellen – die durchschnittliche generierte Wohlfahrt sinkt um 8.2% gegenüber einer vollständig kostenlosen Zuteilung auf 4180 ECU (Wilcoxon-Rank-Sum Test; n=14, z=2.884 und p<0.0039) – sondern es steigt auch die Varianz bzw. die Heterogenität zwischen den Gruppen. Die schwächste Gruppe erreicht nur noch 87% der Wohlfahrt der stärksten Gruppe; ohne Auktion oder bei hälftiger Auktion

[9] Alle statistischen Tests werden auf der Gruppenebene angewendet, da jede Gruppe auf Grund der Interaktion der jeweils sechs Spieler nur eine unabhängige Beobachtung generiert.

beträgt dieser Wert etwa 96%. Diese höhere Heterogenität kann als Abnahme der Stabilität des Zertifikatsystems insgesamt interpretiert werden. Folglich liegt eine erhöhte Unsicherheit bezüglich der zu erwarteten Wohlfahrtseffekte vor, sofern Zertifikate vollständig auktioniert werden.

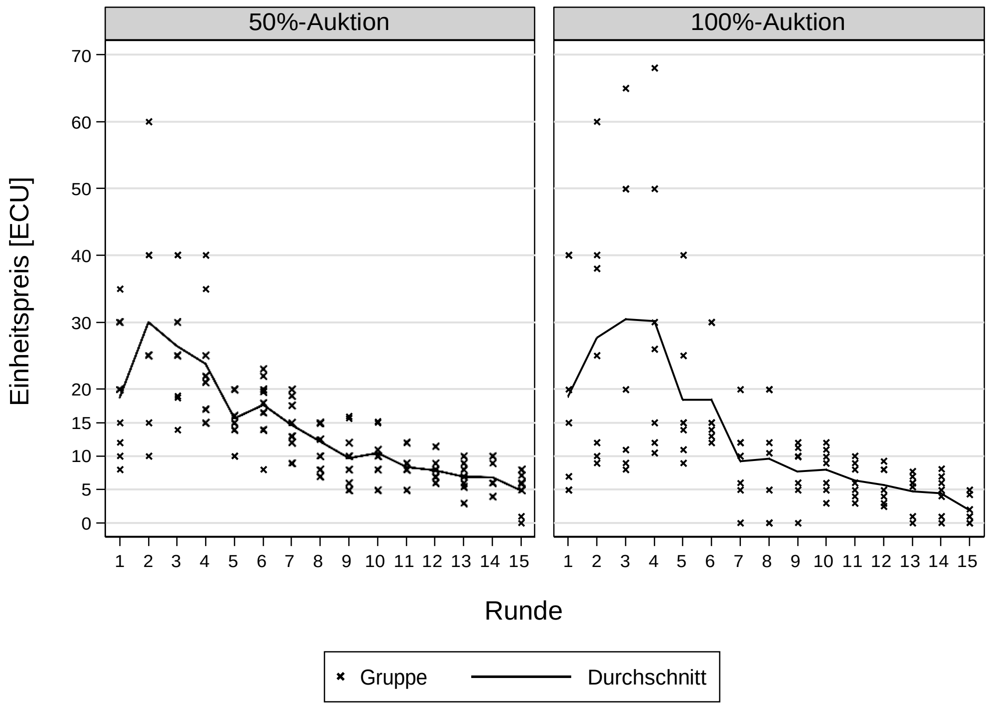
Ergebnis 1: *Eine Regulierung des Flächenverbrauchs durch handelbare Zertifikate ist in hohem Maße effizient, sofern eine kostenlose Primärallokation der Zertifikate erfolgt. Eine hälftige oder vollständige Auktion senkt die Effizienz des Regulierungssystems. Auch die Stabilität, i.S.v. Unterschieden in der Varianz der geschaffenen Wohlfahrt, sinkt im Falle eines Auktionsmechanismus.*

Zertifikatpreise

Aus einer statisch wohlfahrtstheoretischen Sicht ist die konkrete Entwicklung der Zertifikatspreise irrelevant, wirken Transferzahlungen beim Zertifikatkauf ohne Transaktionskosten doch lediglich umverteilend. Allerdings spielt die Zertifikatpreisentwicklung aus Sicht kommunaler Akteure, die langfristig, anhand von festgelegten Budgets planen, eine entscheidende Rolle. Volatile Preise zwingen Kommunen, ihre Planungen unter Unsicherheit bzgl. der Rentabilität von Projekten vorzunehmen. Verzichten Kommunen auf Grund hoher Preisvolatilitäten auf die Akkumulation von Zertifikaten, reagieren sie also mit Zurückhaltung auf Planungsunsicherheit, so können Preisentwicklungen sogar wohlfahrtswirksam werden. Hier muss wieder der Unterschied zu Zertifikatsystemen im Kontext des Emmisionshandels betont werden, da anzunehmen ist, dass Unternehmen als handelnde Akteure anpassungsfähiger im Falle von Preisvolatilitäten sind. Speziell für kleine Kommunen, die ggf. Zertifikate über mehrere Perioden akkumulieren müssen, kann diese Unsicherheit prohibitiv hoch sein, sodass diese gänzlich auf den Erwerb von Zertifikaten und damit auf Außenentwicklungsprojekte verzichten.

Abbildung 3 zeigt die Entwicklung der Einheitspreise in den Auktionen über die Runden.

Abbildung 3. Auktionspreise nach Primärallokationsmechanismus

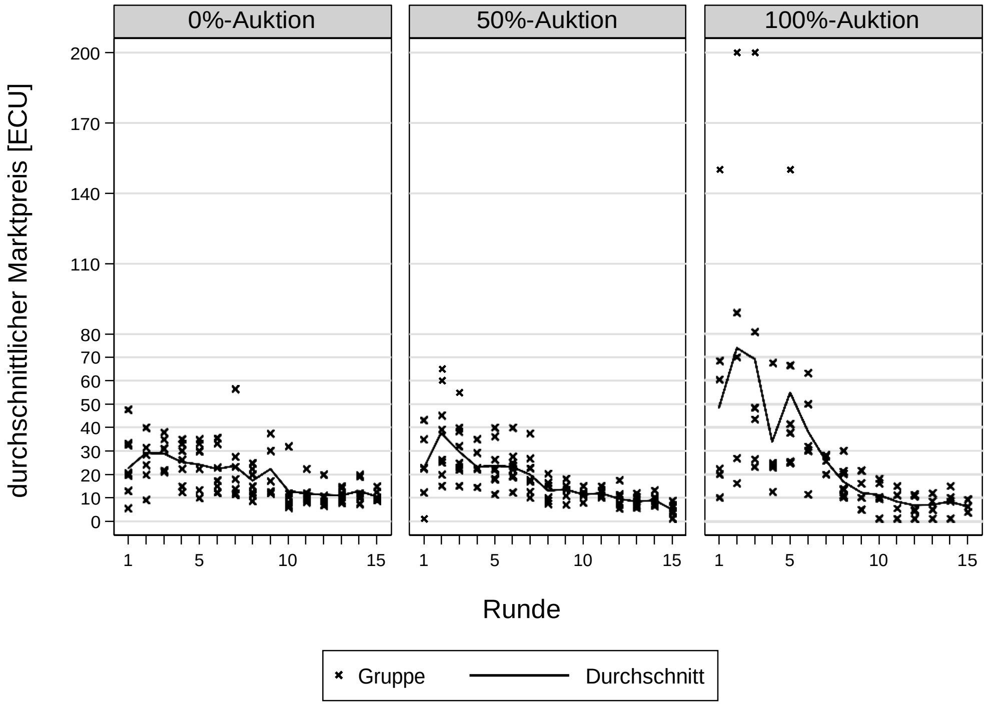


Es ist festzustellen, dass der faire Zertifikatpreis von 11.25 ECU in fast allen Auktionen in der ersten Hälfte des Spiels überschritten wird, zum Teil treten extreme Preisausschläge auf. Die Preise sinken jedoch im Laufe des Spiels ab, was auf Lerneffekte bei den Spielern hindeutet. Interpretiert man die Unterschiede in den Einheitspreisen zwischen den Gruppen als Volatilität, so nimmt diese ebenfalls mit zunehmendem Spielverlauf ab.

Ergebnis 2: *Einheitspreise in den Auktionen der Primärallokation überschreiten den fairen Wert nach Einführung des Zertifikatsystems deutlich und zeigen eine hohe Volatilität, jedoch sinken die Preise und auch die Volatilität über die Zeit.*

Abbildung 4 fasst die Preisentwicklung am Sekundärmarkt zusammen, wobei es aus theoretischer Perspektive kein Unterschied bzgl. des fairen Zertifikatpreis gibt.

Abbildung 4. Zertifikatpreise im Sekundärmarkt nach Primärallokationsmechanismus



Auch im Sekundärmarkt werden anfängliche Preisübertreibungen und die hohe Preisvolatilität über die Zeit abgebaut. Der Verlauf des durchschnittlichen Marktpreises lässt deutlich erkennen, dass unter einer vollständigen Versteigerung Preisübertreibungen und -volatilitäten stärker ausfallen.

Ergebnis 3: *Zertifikatpreise übersteigen im Sekundärmarkt das durch entsprechende Projektwerte gerechtfertigte Niveau. Unabhängig vom Primärallokationsmechanismus sinken die Preise und die Volatilität über die Zeit. Eine vollständige Auktion erhöht die Zertifikatpreise und die Preisvolatilität am Sekundärmarkt.*

Tabelle 5 fasst die Preisentwicklungen anhand der durchschnittlichen Preise und Standardabweichungen in den jeweiligen Spielhälften zusammen.

		Zuteilung	*Mischform*	*Versteigerung*
Auktionspreis (std.)	Runde<=7		**20.99** (2.23)	**21.91** (12.27)
	Runde >7		**8.43** (2.12)	**6.07** (3.37)
Marktpreis (std.)	Runde<=7	**25.14** (4.53)	**27.28** (7.14)	**47.25** (34.74)
	Runde >7	**12.84** (5.05)	**9.70** (1.88)	**10.75** (5.15)

Tabelle 5. Zertifikatpreisentwicklung nach Primärallokationsmechanismus

Zusätzlich zu den beschriebenen Effekten ist festzustellen, dass die Einheitspreise im Primärmarkt das Preisniveau im Sekundärmarkt übersteigen. So liegt bei der *Mischform* der Marktpreis etwa 30% über dem Niveau der Einheitspreise für die erste Hälfte des Spiels, in der zweiten Hälfte sinkt der Preisaufschlag am Sekundärmarkt auf 15%. Unter vollständiger Auktion (*Versteigerung*) vergrößert sich dieser Preisaufschlag auf 115% in der ersten und 77% in der zweiten Hälfte des Spiels. Diese Preisdifferenzen eröffnen die Möglichkeit Spekulationsgewinne zu erzielen, was allerdings nur von wenigen Spielern effektiv genutzt wird. Dies wird daran deutlich, dass sich bei einem starken Spekulationsmotiv die Preisdifferenzen auflösen müssten. Der Preis müsste sich also im effizienten Fall dem einheitlichen, fairen Gleichgewichtsniveau sowohl im Primär- als auch Sekundärmarkt annähern. Die Preisdifferenzen zeigen sich aber persistent, mit der Folge, dass eine ineffiziente Zertifikatallokation erfolgt, was bei vollständiger Zuteilung in dieser Form nicht auftreten kann. Hierfür kann der *Endowment-Effekt* als plausible Erklärung dienen (Kahneman/Knetsch/Thaler 1990).[10] Demnach würden die Zahlungsbereitschaft für den

[10] Der Endowment-Effekt ist eine weit verbreitete und in der Verhaltensökonomik ausführlich erforschte systematische Verhaltensverzerrung. Sie bewirkt, dass Vermögensgegenstände, die sich im Besitz einer Person befinden, von dieser als wertvoller empfunden werden, als wenn sie denselben Vermögensgegenstand nicht besitzen würde. Entsprechend ist die Zahlungsbereitschaft für diesen Vermögensgegenstand geringer, als der

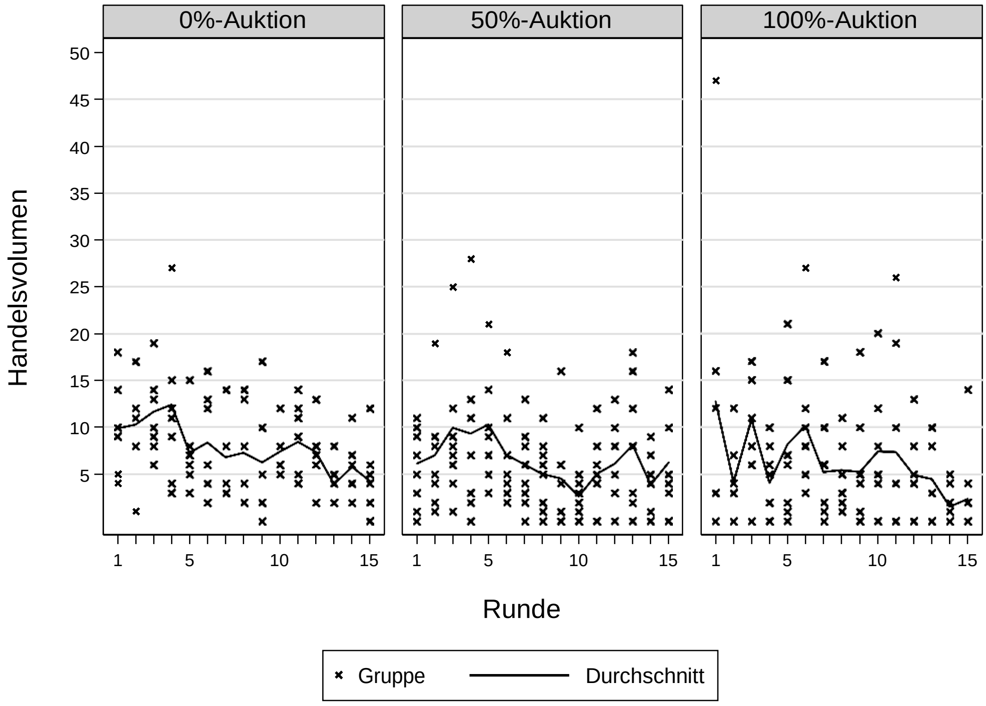
Zertifikatkauf und der Reservationspreis für den Verkauf auseinanderfallen, da einmal erworbene Zertifikate nur gegen einen Preisaufschlag wieder abgegeben werden. Werden durch diesen Effekt weniger Zertifikate gehandelt, obwohl ein entsprechender Tausch eine Besserstellung erlauben würde, wird das Wohlfahrtsoptimum verfehlt. Weiterhin lässt sich die Erwartung ableiten, dass politische Motive das Problem weiter verschärfen. Beispielsweise können Kommunen unabhängig von fiskalischen Motiven Projekte durchsetzen und dadurch einer langfristigen, von den aktuellen Zertifikatspreisen unabhängigen Planung folgen. Einmal ersteigerte Zertifikate würden nur sehr restriktiv, bzw. gegen einen entsprechend hohen Preisaufschlag am Sekundärmarkt gehandelt werden. Hiermit wäre eine zentrale Annahme zur Vorteilhaftigkeit eines Zertifikathandelssystems, die Fähigkeit einer effizienten Allokation von Ausweisungsrechten durch den Marktmechanismus, verletzt.

Ergebnis 4: *Es bestehen substantielle und persistente Preisunterschiede zwischen den Einheitspreisen in den Auktionen (Primärmarkt) und den Marktpreisen (Sekundärmarkt), woraus eine suboptimale Zertifikatallokation und potentielle Ineffizienzen folgen. Diese Preisdifferenzen können mit Hilfe des Endowment-Effekts erklärt werden.*

Um eine vollständige Beschreibung des Handelssystems zu erreichen, stellt Abbildung 5 die tatsächlich gehandelten Zertifikatmengen über die Runden dar.

geforderte Preis bei einem Verkauf. Diese Verhaltensanomalie kann in vielen Situationen zu Ineffizienzen auf Märkten führen.

Abbildung 5. Handelsvolumen über Runden nach Ausgabesystem



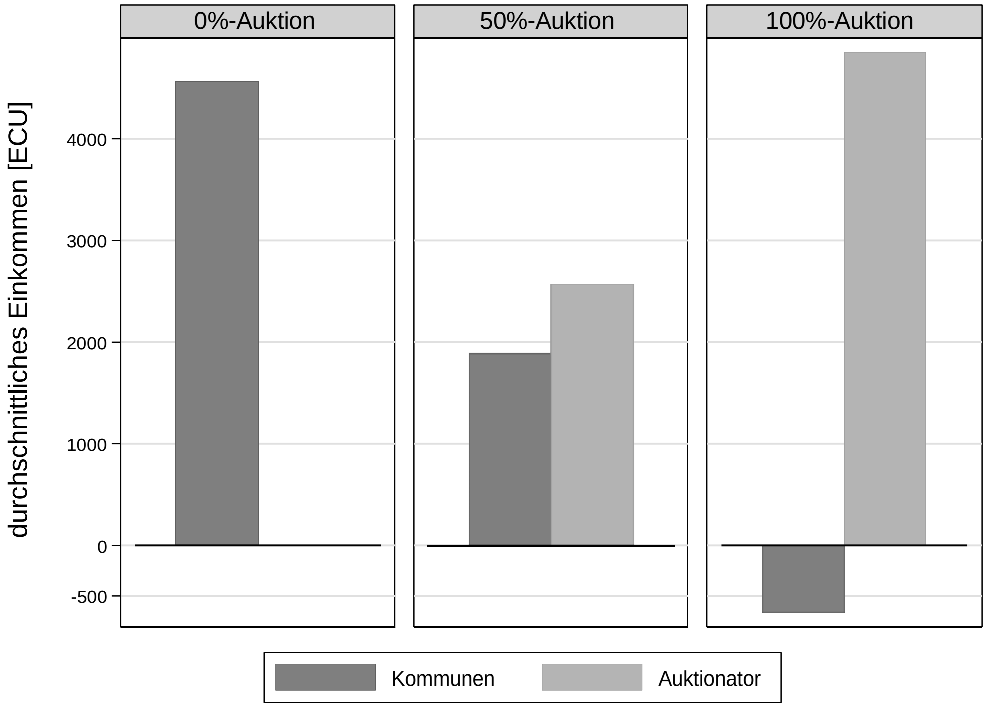
Bei einem über die Runden leicht abnehmenden Trend der gehandelten Zertifikatmengen zeigen sich keine substantiellen Unterschiede hinsichtlich des Primärallokationsmechanismus.

Ergebnis 5: *Handelsvolumina sind im Zeitablauf relativ stabil und unabhängig vom Primärallokationsmechanismus.*

Umverteilungseffekte

Einem System handelbarer Flächenzertifikate ist eine vermögensumverteilende Wirkung immanent. Die konkrete Wirkung wird dabei maßgeblich durch den Primärallokationsmechanismus bestimmt, aber auch der Zuteilungsschlüssel bei kostenloser Primärallokation und die zur Verfügung stehenden Projekte nehmen Einfluss auf die Einkommensverteilung. Der Auktionsmechanismus bewirkt eine Einkommensumverteilung von Kommunen zum (staatlichen) Auktionator, deren Ausmaß in Abbildung 6 abgebildet wird.

Abbildung 6. Umverteilungseffekte des Zertifikathandels

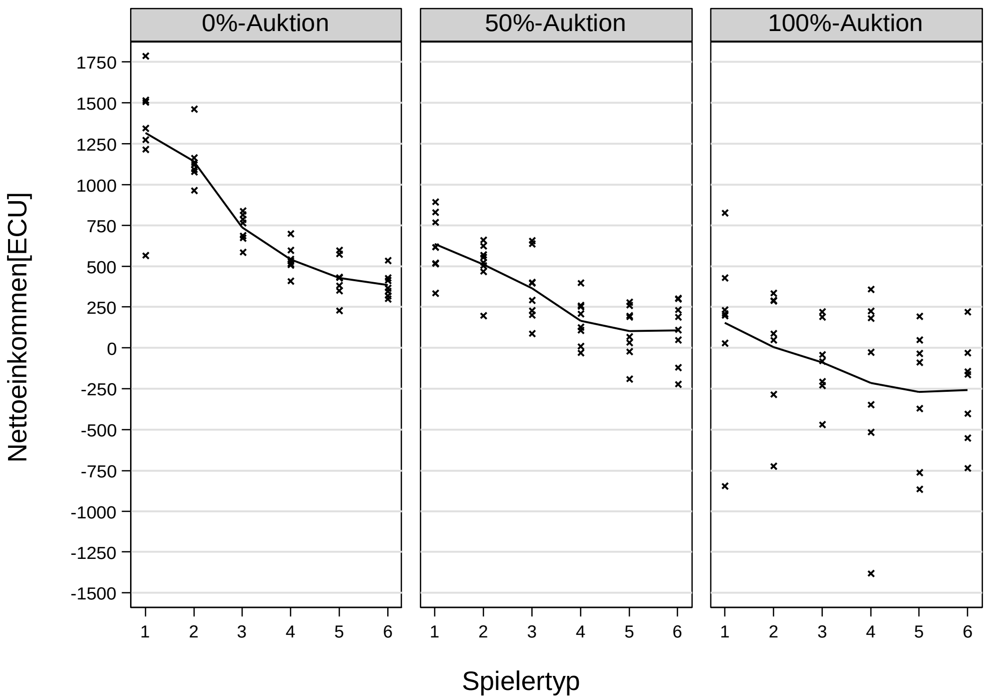


Eine Halbierung der kostenlos zugeteilten Zertifikate lässt das durchschnittliche Einkommen der Kommunen auf weniger als die Hälfte sinken. In der für den Auktionator günstigsten Konstellation, d.h. bei perfekter Preisdiskriminierung, sollte sich ein maximal zu erwartendes Einkommen für den Auktionator von 1875 ECU ergeben (siehe Tabelle 3), welches allerdings um 37% überschritten wird. Dieser Überschuss ist auf das bereits beschriebene Zertifikatpreisniveau im Primärmarkt über dem fairen Niveau zurückzuführen, d.h. den Ausgaben für Zertifikate stehen keine entsprechenden Projektwerte entgegen, da die Grenzkosten für Zertifikate den Grenzertrag übersteigen. Solche Preisübertreibungen zeigen sich noch stärker im Falle einer vollständigen Auktion der Zertifikate. Im Durchschnitt ergibt sich in diesem Fall sogar ein negatives Nettoeinkommen für die Kommunen. Der Auktionator wiederum profitiert von der irrationalen Preisbildung. Die Auktionserlöse übersteigen das nach dem rationalen Kalkül maximal zu erwartende Einkommen von 3750 ECU um 29% (siehe Tabelle 3).

Ergebnis 6: *Die Einführung eines Zertifikatsystems mit einem Auktionsmechanismus zur Primärallokation bewirkt durch Preisübertreibungen eine zu Ungunsten der Kommunen vermögensumverteilende Wirkung, die über das theoretisch zu erwartende Maß hinausgeht und potentiell zu Wohlfahrtsverlusten in der langen Frist führt.*

Das Einkommen der Spielertypen ist im Wesentlichen von den kostenlos zugeteilten Zertifikaten nach dem entsprechendem Zuteilungsschlüssel und den zur Verfügung stehenden Projekten bestimmt. Daher erwarten wir analog zu unserer Parametrisierung, dass das erzielte Nettoeinkommen mit der im Spielertyp reflektierten Größe der Kommune zunimmt. Abbildung 7 illustriert die Einkommensverteilung nach Kommunengröße bzw. Spielertyp, wobei 1 der größten und 6 der kleinsten Kommunen entspricht.

Abbildung 7. Nettoeinkommen nach Spielertypen



Es zeigt sich der erwartete Verlauf eines abnehmenden Nettoeinkommens proportional zur Kommunengröße. Die Summe aus Nettozahlungen für Zertifikate und die Einnahmen durch umgesetzte Projekte entspricht dabei dem Nettoeinkommen. Bei vollständiger Auktion ist wiederum zu erkennen, dass der Auktionator die Zahlungsbereitschaften vollständig abschöpfen und teilweise durch Preisübertreibungen noch darüber hinaus Einkommen erzielen kann. Auch ist die Varianz der erzielten Einkommen deutlich höher als unter teilweise oder vollständig kostenloser Zuteilung. Der Auktionsmechanismus bewirkt darüber hinaus, dass sich durch die Kommunengröße bedingte Einkommensunterschiede verringern, da ohne die kostenlose Zuteilung von Zertifikaten lediglich die unterschiedlichen zur Verfügung stehenden Projekte eine ungleiche Nettoeinkommensverteilung induzieren.

Ergebnis 7: *Eine Primärallokation von Zertifikaten durch einen Auktionsmechanismus senkt insgesamt die Einkommen der Kommunen und erhöht deren Varianz in Abhängigkeit von der Kommunengröße. Dagegen nehmen die Einkommensunterschiede über die Kommunengröße hinweg ab.*

4. Fazit

Die vorliegende Studie trägt zur Diskussion über die Umsetzbarkeit und Ausgestaltung eines Systems handelbarer Flächenzertifikate zur Reduzierung des Flächenverbrauchs bei. Hierfür wird ein ökonomisches Laborexperiment genutzt, das die kontrafaktische empirische Analyse verschiedener Regulierungsalternativen ermöglicht. In diesem methodischen Rahmen zeigt die ceteris paribus Analyse dreier Mechanismen der Primärallokation die Wirkungen auf Effizienz, Verteilungs- und Wohlfahrt.

Obwohl der ökonomischen Theorie zu Folge die konkrete Form der Primärallokation keine Effizienzunterschiede induziert, ergeben sich substantielle Unterschiede zwischen den Mechanismen vollständiger Gratiszuteilung, vollständiger Versteigerung und einer gleichgewichteten Mischform. Zwar hat die Versteigerung im Experiment den Vorteil, dass die Nettoeinkommen weniger abhängig von der Größe der Kommunen sind und gleichzeitig den (politischen) Vorzug, dass keine Einigung über angemessene Zuteilungsschlüssel zwischen den Kommunen erreicht werden muss. Allerdings werden diese Vorteile nach den Ergebnissen der vorliegenden Studie von den Nachteilen überwogen. So führt eine vollständige Auktion der Zertifikate zu Ineffizienzen und einer größeren Instabilität des Systems. Diese drückt sich vor allem durch eine höhere Preisvolatilität aus. Auch die höhere Varianz in der aggregierten Wohlfahrt zwischen Kommunen auf einem Markt und über Märkte hinweg kann als Instabilität interpretiert werden. Darüber hinaus bestehen durch Preisübertreibungen unerwartet starke einkommensumverteilende Effekte zu Ungunsten der Kommunen hin zum auktionierenden Staat. Persistent höhere Zertifikatpreise im Sekundärmarkt gegenüber den Einheitspreisen in den Auktionen der Primärallokation deuten auf einen starken Endowment-Effekt hin, der eine Ursache von Fehlallokationen und damit Ineffizienz ist.

Es ist insbesondere durch die festgestellten Preisübertreibungen zu erwarten, dass finanzstarke Kommunen ein Zertifikatsystem mit Versteigerung dominieren und überproportional profitierten. So wären diese Kommunen auf Grund der Finanzschwäche der anderen Akteure in der Lage, Zertifikate aufzukaufen und damit Projekte mit einem hohen Flächenverbrauch unabhängig von deren tatsächlicher Rentabilität durchzusetzen. Gegeben der Budgetbeschränkung finanzschwacher Kommunen und einer Zertifikatversteigerung als Primärallokationsmechanismus würde das gesamte System seine effiziente Lenkungswirkung verlieren. Auch theoretisch werden unter diesen Bedingungen nicht mehr die rentabelsten Projekte durchgeführt, wodurch das Wohlfahrtsoptimum verfehlt wird und eine extreme Konzentration des Flächenverbrauchs entsprechend der finanziellen Ausstattung resultiert.[11]

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[11] Für eine grundlegende Kritik eines Systems handelbarer Flächenzertifikate auf Grund potentieller Fehlsteuerungen zu Gunsten finanzstarker Kommunen vgl. Löhr (2005, 2006, 2012), dessen Analysen durch die hier gezeigten Ergebnisse, vor allem in Bezug auf die Notwendigkeit einer kompensierenden staatlichen Umverteilungskomponente, ergänzt werden können.

Eine teilweise oder vollständige Gratiszuteilung von Zertifikaten kann dieses Problem deutlich abmildern, da finanzschwache Kommunen diese Zertifikate ansparen können, um so rentable Projekte durchzuführen oder Einkommen durch den Verkauf zu erzielen. Auch eine Rückerstattung der Erlöse des Auktionators an die Kommunen zur Beschränkung der finanziellen Belastung ist insofern problematisch, als diese Rückerstattung sehr wahrscheinlich wohlfahrtssenkende, verzerrende Wirkungen hervorruft und zudem Transaktionskosten entstehen.

Von einem wirtschaftspolitischen Standpunkt mit den Zielen höherer Effizienz und Stabilität zur Erreichung von Planungssicherheit unterstützen die Ergebnisse der vorliegenden Studie die Gratiszuteilung als Primärallokationsmechanismus in einem System handelbarer Flächenzertifikate.

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Workingpaper Nr. 2

Experimental evidence on the resilience of a cap & trade system for land use in Germany

von

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Experimental evidence on the resilience of a cap & trade system for land use in Germany

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Abstract: The German government has committed to substantially limiting future land consumption. Among the most prominently discussed policy instruments is the implementation of a cap & trade system for land consumption, in which a limited amount of certificates is allocated to and traded by municipalities. Since these certificates would be a prerequisite for conducting building projects, this system is expected to reduce urban sprawl and foster the efficient allocation of land consumption projects. While previous empirical studies have supported these projections, the potential fragility of a cap & trade system in the case of macroeconomic shocks has not been considered. In three laboratory experiments, we simulate the impact of economic and budgetary crises within a cap & trade scheme for land consumption. We find that a market-based system succeeds in compensating macroeconomic disturbances with only minor welfare losses. Certificate prices in auctions and trading are somewhat more volatile before shocks, yet normalize afterwards. Trading volumes and the specifics of project realizations remain largely unaffected. Unrelated to the macroeconomic shocks, auction and market prices persistently diverge, leading to income redistributions to the state. Overall, our evidence supports the introduction of a market-based certificate scheme to reduce land consumption in Germany due to its resilience against potential shocks.

Keywords: auction, economic experiment, government deficit, land consumption, tradable planning permits, urban sprawl

JEL Classification: C91; C92; D8

1. Introduction

Policy options for reducing land consumption to preserve natural resources and biodiversity have been broadly discussed in recent years. Accordingly, a large number of different urban containment strategies have been proposed, implemented and evaluated, particularly in developed countries (see e.g. Anthony, 2004; Bengston et al., 2004; Millward, 2006; Gennaio et al., 2009, Menghini et al., 2015). Within the scientific and regulatory debate, environmental economists frequently point to the advantages of market-based instruments in reconciling the reduction of urban sprawl with economic growth (Nuissl and Schroeter-Schlaack, 2009). In Germany, one of the most prominently discussed instruments among environmental economists and legislators is the implementation of tradable certificates for land consumption, i.e. a cap & trade system for land consumption (Henger and Bizer, 2010). While previous market-based schemes for preserving open spaces have been confined to particular communities or regions, e.g. tradable development rights (TDR) in the United States (Johnston and Madison, 1997; Bengston et al., 2004), proponents of a cap & trade system in Germany call for a nationwide implementation controlled by the federal state. German economists and government agencies argue that this system could substantially reduce land consumption, while at the same time market forces would lead to certificates being allocated to the communities that could conduct the most valuable building projects. Thus, the economically most valuable building projects would continue to be realized despite the overall cap on land consumption (Henger and Bizer, 2010).

The discussion in Germany has been driven by numerous studies issued by governmental agencies following the 2002 federal government's commitment to reducing the land consumption to 30 Hectares per day by 2020 (Federal Government, 2002), which has been renewed in 2013 (Coalition Treaty, 2013). These studies present theoretical evidence and weigh different policy options of implementing a cap & trade system for land consumption. The scientific discussion has evolved similarly, having considered a number of relevant institutional, political and judicial factors for an implementation in Germany, for which Henger (2010) provides a comprehensive literature review with Davy (2009) and Fischer et al. (2013) contributing critical assessments.

However, a shortcoming of the discussion is a lack of empirical evidence analyzing the feasibility and potential shortcomings of a cap & trade system for land consumption. A large theoretical literature has evolved discussing the advantages and potential restrictions to a system of tradable certificates for land consumption. The core arguments include the superior efficiency of a reduction on land consumption; the precision of a system that uses a fix quantity of land and variable prices, which is unattainable within a direct regulation of prices; the argument that a cap & trade system on land stimulates more efficient land consumption by decision-makers and fosters inner city development; and it is assumed that the necessity of taking part in the trading scheme will increase policy-makers' awareness of the ecological problems associated with land consumption (Henger, 2010).

However, only two field experiments have been conducted with officials from German municipalities to date, who are responsible for planning and approving building projects in Germany, as reported in Henger (2013). The field experiments implement a cap & trade system for land consumption considered as an attainable and realistic policy option. Both studies find that the system realizes an externally fixed cap on land consumption, while providing a satisfactorily efficient reallocation of excess certificates to the most valuable projects. Transferring the field experiments to the economic laboratory, Henger (2013) shows that student participants achieve more efficient allocations compared to municipal agents. In more recent experimental contributions, Meub et al. (2014) show the distortive influence of political business cycles to a cap & trade system for land consumption and Meub et al. (2015) investigate different allocative mechanisms.

While the limited empirical evidence emphasizes that the trading system envisioned by federal agencies is an efficient allocative and redistributive mechanism, we argue that many potential influences on the effectiveness of such a system have not been considered. In particular, the system's resilience against exogenous shocks has not been analyzed to date. Consequently, the theoretical arguments only hold for the (fairly unlikely) case of long periods of macroeconomic stability. We thus argue that the cap & trade system's resilience should be a central empirical research goal, understood as its ability to uphold the efficiency and applicability when confronted with sudden exogenous changes to its core parameters. In our experimental setting, we chose to implement a recent issue that is likely to have a substantial impact on the stability of a cap & trade system for land use in Europe, namely the issue of economic crises and critical public budget deficits. Firstly, abrupt firm bankruptcies and the ensuing movement of labor are likely to reduce the value of potential building projects as the demand for land consumption decreases in areas of rapidly shrinking populations. Secondly, we investigate the issue of imminent budget restrictions, which may limit municipalities' ability to buy certificates when considered optimal from a cost-benefit perspective, which is a necessary condition for the system's overall efficiency. Both issues can happen within short periods of time so municipalities are faced with abrupt changes in land values and budgetary restrictions. For instance, consider the case of an economic crisis that could lead to a rapid reduction in local tax revenues or massive emigrations due to the loss of industrial jobs following company bankruptcies. Particularly in smaller and medium-sized municipalities, the loss of a single larger company or government institution, e.g. military installations, could dramatically reduce tax revenues and lead to the emigration of employees, whereby the value of all building sites is substantially reduced over a short period. These – largely unpredictable – exogenous shocks reduce municipalities' ability to rationally plan the costs and benefits of buying and selling certificates for land consumption. We therefore aim at investigating this potential disturbance to the efficient working of a cap & trade system for land consumption.

To address our research agenda, we pursue the methodology of experimental economics, which enables us to empirically answer counterfactual questions that are inaccessible through empirical studies based on field data. This approach allows us to simulate how subjects in a system of tradable planning permits act when confronted with an environment of potentially severe macroeconomic disturbances. While the use of student subjects in experimental studies leads to certain issues in terms of external validity, the resulting empirical evidence provides behavioral insights that theoretical and classical empirical analyses cannot generate. We build our analysis of a cap & trade system's resilience under an uncertain macroeconomic environment upon an experimental design that implements the core features of the cap & trade system planned within the German administration and tested in field experiments (Henger, 2013), whose details are described in section two.

Our investigation broadly builds on two strands of literature. Firstly, our experimental design, as well as the previous studies on tradable planning permits, is motivated by the empirical literature on various aspects of CO_2 emission certificates (see Wrake et al., 2012) for a comprehensive literature review), which has been accompanied by experimental studies early on (see e.g. Grimm and Ilieva, 2013; Goeree et al., 2010; Benz and Erhard, 2007; Fischer and Fox, 2007). Our experimental setting loosely implements these previous considerations and experimental parameters. However, we necessarily deviate to account for the specifics of land consumption rather than emissions.

Secondly, our motivation to pursue the consequences of macroeconomic disturbances within a system of tradable planning permits is based upon the discussion of the debt crisis faced by municipalities across Europe, which is connected to the broader economic crisis, both of which calls the successful implementation of a cap & trade system into question. Thus, the financing of certificates for land consumption could become problematic for many heavily indebted municipalities. Further, the decline of regional firms and the shutdown of government programs could lead to a substantially decreasing demand for potential building sites and thus substantially decrease the value of potential building projects. Potential problems caused by budgetary and economic crises within a cap & trade system would universally apply to all European states. We can thus base our study on a broad strand of contributions that discuss the effects of fiscal crises on the municipal level across European states. Comprehensive overviews regarding the reactions of federal states and municipal governments to the most recent fiscal crises following the financial- and the euro crisis are provided by Silva (2014) and Cotarelli and Guerguil (2014). A more detailed look into fiscal rules and deficits across Europe is provided by Foremny (2014), who empirically investigates the pre-crisis years and the fiscal performance of local governments; an institutional perspective on local government reform with a focus on the post-2008 crisis years in Europe is offered by Hlepas (2015). Glumac et al. (2014) discuss the reactions of Dutch municipalities to the financial crisis and the ensuing financial problems with a special focus on land use decisions.

Consequently, our study builds upon the previous, mostly theoretical work on tradable planning permits in Germany, implements experimental settings from studies of emissions certificates and is motivated by the discussions on the economic and budgetary crises in Germany and Europe. Combining these aspects, we are able to provide novel, policy-relevant evidence on the stability of a cap & trade system for land consumption given an uncertain macroeconomic environment. The remainder of this paper is structured as follows. Chapter 2 introduces our experimental design and chapter 3 details our theoretical benchmark model. Chapter 4 presents the results, chapter 5 discusses our results and chapter 6 concludes.

2. Experimental design

In the following, we describe the five core features of our experimental design: first, the course of the game; second, player and project specifics; third, the payoff structure, i.e. the way monetary incentives for players are designed; fourth, we provide information on the treatment conditions implementing the exogenous shock and the procedure; subsequently, in chapter three, we present the theoretical benchmark model for rational decision-making as well as the expected results for the two main variables. Note that the general design is based upon the experiment by Meub et al. (2014).

2.1 Course of the game

Our design implements the state of planning by the German Federal Environmental Agency, which has also been used to conduct field experiments (Henger, 2013), and transfers it to a laboratory experiment. Subjects simulate the role of municipal decision makers, who are tasked with accumulating tradable planning permits and subsequently realize land consumption projects. There are fifteen periods, each with three stages.

In the first stage, 24 certificates are allocated to subjects, half of which are issued using a uniform price auction with sealed bids, whereby subjects enter a quantity and price. The bids are subsequently ranked and the available quantity of certificates is assigned. The price for all certificates (uniform price) is the price for the last certificate granted, i.e. the one with the lowest price. The other half of the certificates are issued for free ("grandfathered").

In the second stage, subjects can trade certificates in a double auction market for three minutes with no limits on prices or quantities, as well as no transaction costs. Thus, subjects can sell excess certificates, buy additional ones from others or gamble on price variations.

In the third stage, subjects can use their certificates to realize one project per period, which yields a payoff. The projects simulate land consumption projects with different values. Certificates can be saved for further periods, yet they expire at the end of the game with no payoff given. Figure 1 gives an overview of the course of the game in each period.

Stage 1: allocation of certificates	**Stage 2: trade**	**Stage 3: project realization**

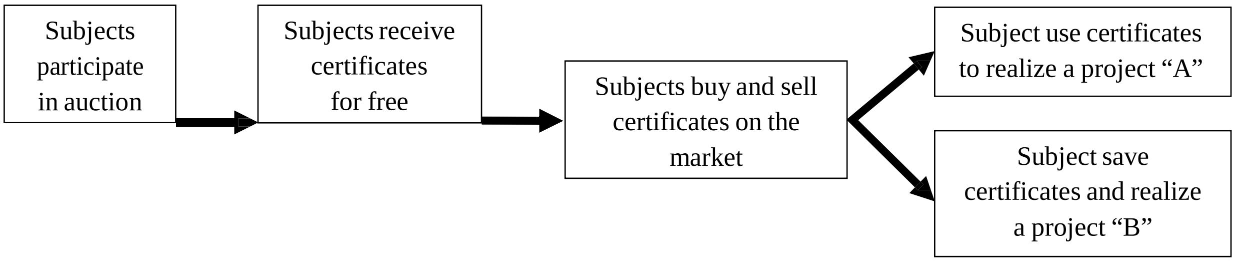


Figure 1. Overview of one period of the game

2.2 Player and project specifics

At the beginning of the game, subjects are randomly assigned to markets of six players, henceforth denominated as “societies”. Each market comprises six different types of players, to which subjects are assigned randomly. These player types simulate municipalities of different sizes, each of which have a specific pool of 45 potential projects.

These projects are differentiated into “Type A” and “Type B” projects. Type A projects simulate the land consumption in outskirt areas. All Type A projects require eight certificates for realization. For reasons of simplicity of the game structure, we assume that all outskirt building projects require the same number of certificates, which – while substantially increasing the comprehensibility of the game to participants – does not violate the basic features of a cap & trade system for land consumption. Type B projects simulate inner-city developments, which state legislation aims at increasing at the expense of outskirt development. Consequently, Type B projects do not require any certificates for realization but at the same time lead to a lower payoff. Projects of Type A yield 100/80/60/40/20 experimental currency units (ECU), whereas Type B projects always yield 10 ECU. The different player types are assigned different project pools, whereby the players simulating larger municipalities are assigned more valuable projects. Furthermore, the larger municipalities are grandfathered a higher number of certificates per period, which implements an issuance formula based upon the population of municipalities, as planned by the German Federal Environmental Agency (Henger et al., 2010). We assume that the state issues enough certificates to allow half of the municipalities to realize an outskirt development project per period, i.e. implementing a cap on land consumption of 50%. Thus, twelve certificates are grandfathered in each period, whereby the different player types are given between one and four certificates. Players are not informed about other players' specific projects. However, they do know that all players can activate projects worth 0-100 ECU and that Type B projects are uniformly worth 10 ECU. The information about player types and assigned certificates is provided in Table 1.

project	**number**	1	2	3	4	5	6	7			
	value	100	80	60	40	20	0	10			
	type	A	A	A	A	A	A	B			
	certificates	8	8	8	8	8	8	0			
player										**certificates period (total)**	
	#projects for								**total**	#grandfathered	#auctioned
	1	10	8	6	4	2	0	15	**45**	4(60)	-
	2	8	10	6	4	2	0	15	**45**	3(45)	-
	3	6	8	10	4	2	0	15	**45**	2(30)	-
	4	4	6	8	10	2	0	15	**45**	1(15)	-
	5	2	4	6	8	10	0	15	**45**	1(15)	-
	6	0	2	4	6	8	10	15	**45**	1(15)	-
	total	**30**	**38**	**40**	**36**	**26**	**10**	**90**	**270**	**12(180)**	**12(180)**

Table 1. Overview of players, projects and certificates.

Note: The upper half of the table gives the project specifics: 7 projects are available with different values; the first six are denominated "A" and require 8 certificates for completion, the last one is denominated "B" and requires no certificates. The lower left half gives the player specifics. Player types 1-6 each have a different number of projects at their disposal: player 1 e.g. can complete 10 "number 1" projects, 8 "number 2" etc. All players have the same sum of projects overall (45). The right hand column indicates the number of certificates that are grandfathered each round and – in brackets – the overall number allocated to the respective player type. Since certificates are auctioned, no fix amount per player can be indicated.

2.3 Payoff structure

The payoff structure describes how monetary incentives for decision-making in our setting are specifically designed. It comprises three parts: first, there is an initial endowment of 700 ECU; second, the net payments for certificates; and third, the payoff from the realization of projects. Payoffs and prices are denoted in ECU, with 100 ECU converting to 1€ for the final payment. Additionally, subjects receive a show-up fee of 4€, which is otherwise unrelated to the game.

The initial endowment enables all players to participate in the auction and buy certificates from other players. Buying in the auctions and the market is restricted by a player's budget constraints, given that there is no borrowing in the game. The payoff from conducting projects is paid at the end of the game, thus simulating that returns from municipal investments in land consumption projects are often realized in the long term.

2.4 Treatment conditions

There are three treatments analyzed in this paper. Firstly, we run a benchmark treatment that incorporates the experimental design described above and enables a comparison to a setting without exogenous shocks.

I. Benchmark Treatment (BASELINE)

Additionally, we implement two treatments to assess the effect of sudden exogenous shocks. Therefore, we can analyze the effects resulting from macroeconomic instability for the cap & trade system regarding the overall efficiency, price volatility, the distribution of welfare gains across the different player types and overall trade volume.

II. Economic downturn resulting in the reduced profitability of land consumption projects (VALUE)

The second treatment implements the sudden reduction of land consumption projects' values, potentially caused by a strong decrease in demand for building projects due to decreasing populations. Obviously, another plausible treatment condition would be to implement shocks asymmetrically, thus simulating e.g. the relocation of government facilities or large companies from one municipality to another. However, we chose to investigate symmetric shocks, as they are closer to larger macroeconomic disturbances with a potentially stronger impact on the efficiency of a cap & trade system. Accordingly, the value of land consumption projects drops along with decreasing demand. This is implemented after period 7, whereby all remaining projects worth 100 ECU and 80 ECU are reduced to being worth 60 ECU. Players are told in the instructions that a shock will occur, but they do not know the timing, magnitude and direction of the change in project values.

III. Economic downturn resulting in budgetary cuts (BUDGET)

We assume in our third treatment that the reduction of municipalities' budgets is among the most relevant exogenous shocks affecting the workings of a cap & trade system for land consumption. We thus implement a budgetary cut after period 7 of 15, which substantially reduces players' budgets to 75 ECU. The remainder of their budget is not available from period 8 onwards, but is paid to subjects at the end of the game. Thus, the budget is not lost;

rather, it is frozen and unavailable to finance further projects. All subjects are told in the instructions that their budgets will be frozen and replaced by a new budget at a specific point in the game, whereby the frozen budget will be paid to them afterwards. However, subjects know neither their new budget nor the specific timing of the budget cuts. Both such issues can be considered realistic assumptions when simulating economic crises and the loss of tax income for municipalities caused e.g. by companies' reduced revenue or potential bankruptcy. Figure 2 provides an overview of our three treatments and their respective changes within the game.

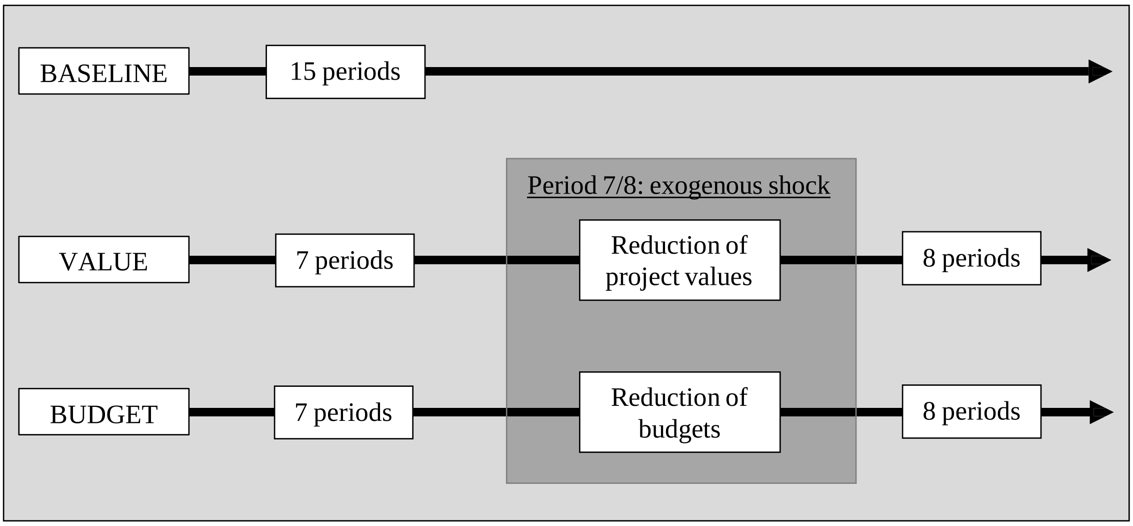


Figure 2. Visualization of the treatment effects for BASELINE, VALUE and BUDGET in the course of the game

2.5 Procedure

Table 2 shows our treatment manipulations and the numbers of participating subjects. Note that the baseline treatment is also used in Meub et al. (2014).

Treatment	Budgetary cut	Value reduction	No. of participants	No. of societies
BASELINE	No	no	48	8
VALUE	No	yes	48	8
BUDGET	yes	no	48	8
total			**144**	**24**

Table 2: Summary of treatments and participants.

Our experiments were conducted in ten sessions in October 2014. We used z-Tree (Fischbacher, 2007) in the Laboratory for Behavioral Economics at the University of Goettingen and ORSEE (Greiner 2004). Participants were only allowed to participate in one session. The understanding of the game was assured by running mandatory control questions and answering questions to subjects beforehand. Overall, sessions had a duration of about 80 minutes, with an average payment of 14.64€. Subjects studied various academic disciplines (31.3% were students of economics as the largest subgroup). Subjects were on average 25.3 years old and 54.2% were female.

3. Theoretical benchmark model

To establish a benchmark of optimal decision-making, we firstly consider the case of decisions when no cap on land consumption is in place. Since all Type A projects are more profitable than Type B projects, this scenario would lead to the 90 most profitable Type A projects being realized (1 project per period times 15 periods times 6 players). Once the 50% cap on land consumption is introduced, only three projects per period can be realized, i.e. 45 projects overall (3 projects per period times 15 periods). As all Type A projects require eight certificates, the state needs to restrict the number of issued certificates to 24 per period to achieve this regulatory goal. Type B projects still do not require certificates.

To calculate the equilibrium prices for certificates, we can derive the individual willingness to pay (WTP). A player realizing a Type A project has opportunity costs of 10 ECU for not realizing a Type B project. Furthermore, realizing the most valuable project yields 100 ECU and requires eight certificates. The WTP can then be derived as (100-10)/8=11.25 ECU. There are 30 Type A projects worth 100 ECU overall, which is unknown to the players. Thus, players act rationally if their WTP amounts to 11.25 ECU per certificate, given that they are endowed with 100 ECU projects that can be realized. Once all of these projects have been realized, prices need to drop to (80-10)/8=8.75 ECU. Rational players sell certificates as long as market prices exceed these fair prices and they buy if they are lower. This leads to the prediction that prices in BASELINE should always be between 11.25 ECU and 8.75 ECU per certificate.

To predict which players will realize which projects when their WTP is equal, we assume that certificates will be allocated according to player types in descending order and that players will pay 11.25 ECU for projects worth 100 ECU and 8.75 ECU for projects worth 80 ECU. Please note that with the certificates valued at the fair price, the distribution of the 80 ECU projects has no effect on overall welfare. We assume that grandfathered certificates are distributed evenly between 100- and 80 ECU projects.[1] The subsequent Table 3 shows the project realization and welfare resulting from rational decisions and the assumptions described above. “Net transfer” refers to the income of the state yielded in the auctions.

project	**number**	1	2	7						
	value	100	80	10						
	type	A	A	B						
	certificates	8	8	0						
player						**certificates total**		**value**		
	#projects for				**total**	#used	#bought(free)	gross	net transfer	net
	1	10	5	0	**15**	120	60(60)	1400	625	775
	2	8	5	2	**15**	104	59(45)	1220	607	613
	3	6	5	4	**15**	88	58(30)	1040	587	453
	4	4	0	11	**15**	32	17(15)	510	191	319
	5	2	0	13	**15**	16	1(15)	330	11	319
	6	0	0	15	**15**	0	-15(15)	150	-157	307
	total	**30**	**15**	**45**	**90**	**360**	**180(180)**	**4650**	**1864**	**2786**
	value	**300 0**	**12 00**	**450**						
	certificates	**240**	**12**	**0**						
0										

Table 3. Optimal project realizations in BASELINE.

Note: The upper part of the table shows how many projects should be realized given optimal behavior by all players; the description of project numbers etc. is similar to table 1. The lower left part of the table shows which player should rationally realize the specific projects. Again, the denomination is similar to table 1; each player should realize 15 projects of different values. The lower right part of the table shows how many certificates should be used by each player, how many certificates should be bought/grandfathered, what the gross value of these projects would amount to, the net transfer for buying the certificates given fair prices and, finally, the net gain for each player type given universally optimal behavior. Note that numbers are rounded to integers and that “free” refers to certificates that were grandfathered.

As Table 3 shows, given rationality, there should be 45 realizations of Type A, i.e. 30 worth 100 ECU and 15 worth 80 ECU, as well as 45 of Type B. This would represent the most efficient solution given the regulatory objective. The individual players’ income consequently relies on the projects available to them, as well as to the number of certificates grandfathered. The net transfer is the maximal income of the state (auctioneer), which transforms the players’ surpluses to state revenue in the auction. Accordingly, payments in the auction transfer income from individuals to the state, while trading transfers income among players.

[1] Consider the example given in Meub et al. (2014), where player 1 realizes ten 100 ECU projects and five 80 ECU projects, while being grandfathered 60 certificates. It is then assumed that the respective player uses two-thirds of these grandfathered certificates for the projects worth 100 ECU and one-third for the 80 ECU projects. The additionally necessary 60 certificates lead to costs of 40 certificates at 11.25 ECU and 20 certificates costing 8.75 ECU.

Inefficiencies in this system only occur if players fail to use their certificates rationally by realizing inferior projects, e.g. when realizing a 60 ECU project, even when a 100 ECU project is available.

3.1 Rationality in VALUE

The change in optimal behavior in *VALUE* follows the standard WTP calculation. The WTP should shift to adjust for the decrease in project profitability. The most valuable projects are now worth 60 ECU, which gives a WTP of (60-10)/8=6.25. While equilibrium prices drop, the total welfare generated - as measured by the aggregate value of realized projects - should decrease according to the downgrade of 100 and 80 ECU projects. Until period 8, 168 certificates can be used to realize 21 Type A projects worth 100 ECU, with a total net value of 2100 ECU. In the second half of the game, 192 certificates remain, allowing for the realization of 24 Type A projects worth 60 ECU with a total net value of 1440 ECU. Adding these numbers to the 450 ECU of the 45 realized Type B projects yields the maximum aggregate project values, which amounts to 3990 ECU.

However, there are distributional effects resulting from the shift in project values. The state's income decreases as auction prices also drop to the new equilibrium of 6.25 ECU. The state auctions 84 certificates within the first seven periods, which gives a maximal income of 945 ECU when the WTP of 11.25 ECU determines auction prices. In the second half of the game, 96 certificates are auctioned at 6.25 ECU, leading to an income of 600 ECU. Overall, the maximal income for the state amounts to 1545 ECU.

Furthermore, since larger municipalities have more valuable projects, they also lose more potential projects after period 7. Moreover, they might realize fewer Type A projects because the WTP of all players becomes equal as all players now have 60 ECU projects. Therefore, it is unclear whether Type A projects are realized in larger municipalities, although this is irrelevant from a welfare perspective.

3.2 Rationality in BUDGET

All considerations regarding the optimal behavior remain valid for BUDGET until period 8, when all budgets are frozen and players are endowed with 75 ECU. Given the equilibrium price of 11.25 ECU, players are only able to buy six more additional certificates, which results in a total of 36 certificates for the last eight periods, although 96 certificates are sold. Accordingly, prices drop and the WTP ceases to determine equilibrium prices. Since players are not informed about the other players' budgets, they cannot calculate the new equilibrium prices beforehand. Prices might thus continue to be fairly high for a number of periods before the budget constraints become binding. This results in lower prices, which in turn considerably reduces the state's (auctioneer's) income.

The income of the auctioneer up to period 7 should amount to 945 ECU, with 84 certificates being sold at 11.25 ECU. From period 8 to 15, the state should be able to generate income equal to the sum of the players' budgets, i.e. 75 ECU for six players, which gives 450 ECU. This sum corresponds to an average certificate price of 4.6875 ECU (=450/96). Overall, the states income should amount to 1395 ECU.

However, it is important to note that total welfare only depends on the projects realized. Therefore, whether certificates are allocated efficiently depends on the specific price dynamics. Accordingly, no clear prediction can be made concerning whether the system will continue to efficiently allocate certificates.

Note that we test the robustness of a cap & trade system against macroeconomic disturbances by distinctly leaving the expected total value of projects realized unchanged in *BUDGET*. Our considerations regarding optimal behavior assume fully rational agents with the mutual expectation of rationality and perfect foresight, which excludes speculation motives or path dependencies. While the assumptions of a perfect ex-ante evaluation and rational decision-making by all players are of course unrealistic, they serve as a benchmark to evaluate systematic deviations from the rational market outcomes produced by our treatments.

3.3 Indicators and expected results

Before presenting our results, let us briefly discuss the expected results based on our benchmark model regarding the two core parameters efficiency and distribution of income.

Efficiency

In our experiment, welfare can be assessed by the aggregate value of realized projects. Since welfare only depends on project realizations, all transfers made in the auctions or the inter-municipality market merely redistribute income. This perspective assumes that income for the auctioneer (the state) adds to aggregate welfare as much as the income achieved by the municipalities. Consequently, inefficiencies can only arise from the realization of projects that are inferior in value when superior projects were available.

Since project values are lower in *VALUE* for the second half of the game, we cannot compare treatments by the absolute value created through project realizations. We thus compare treatments using the ratio of actually created value through project realizations and the maximal aggregate project value, which is the optimal outcome from an aggregate welfare perspective. As shown in section 3, the optimal outcome for *BASELINE* and *BUDGET* is given by the realization of 45 Type A projects: 30 worth 100 ECU and 15 worth 80 ECU. For *VALUE*, no such projects are available in the second half of the game. It follows that the maximal aggregate value amounts to 4650 ECU for *BASELINE* and *BUDGET* and only 3990 ECU for *VALUE*. Accordingly, we divide the aggregate value created by every society of six players by the respective maximum for each treatment.

Distribution of income

Although distributional effects are irrelevant from a welfare perspective, the political feasibility might crucially depend on whether municipality characteristics lead to disproportionate benefits within a cap & trade system; for instance, consider the problem of market power by large cities capable of influencing prices within the secondary, inter-municipality market for certificates. Similarly, the distribution of incomes between the state and the municipalities may substantially influence the political feasibility of a cap & trade system.

The income distribution between the state and municipalities is exclusively determined by the payments in the auctions. As shown in section 3, we expect the state's income to decrease once there are budgetary or shocks in land value. For a comparison of treatments, we calculate the state's income in relation to the maximal income, which is derived by assuming perfect price discrimination and optimal behavior of all subjects. Recall that the aggregate income of municipalities is determined by the aggregate value of the realized projects minus the transfers to the state in the auctions. Again, the aggregate income of municipalities is defined in relation to the maximal achievable income by optimal behavior.

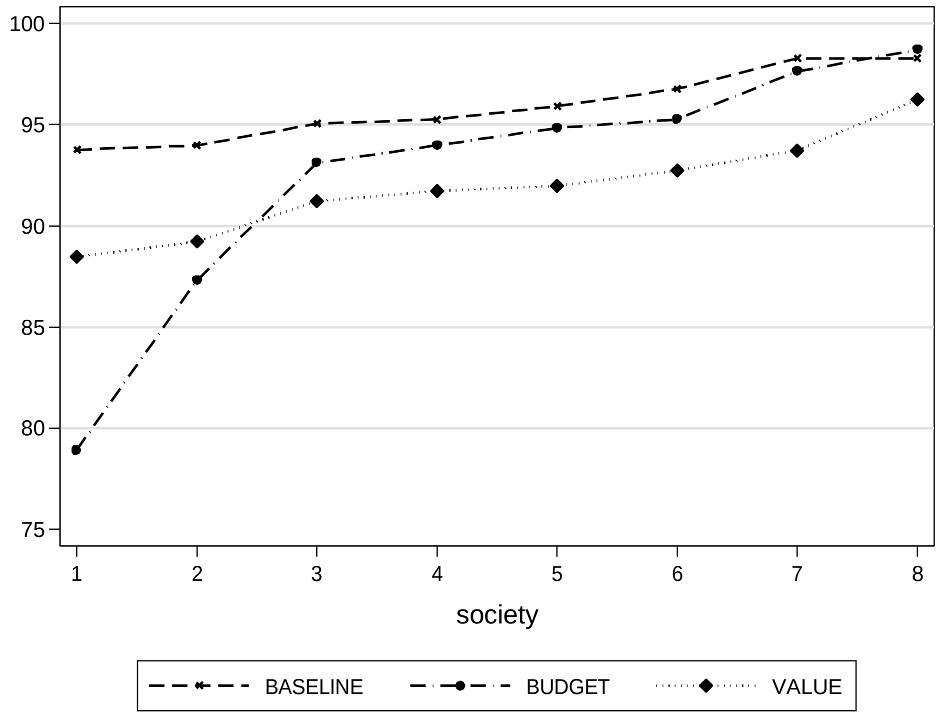
4. Results

Our results are presented in four sections to provide an assessment of the cap & trade system's efficiency and stability: first, we assess overall efficiency; second, we consider the distribution of income conditional on municipality size, as well as between the state and municipalities; third, we illustrate the distribution of realized outskirt land consumption projects conditional on municipality size; fourth, we analyze the prices in the auction and the certificate market to assess the stability and dynamics of the cap & trade system. Fifth, we evaluate the trading volume as an alternative indicator. Overall, the combination of these indicators allows us evaluate the stability of a cap & trade system for land consumption in the face of macroeconomic disturbances.

4.1 Efficiency

Figure 3 presents the degrees of efficiency across treatments for the respective societies.

Figure 3. Efficiency by treatments



It can be seen that the cap & trade system proves fairly efficient across treatments and societies. *BASELINE* seems to lead to higher degrees of efficiency on average (95.9%) when compared to *BUDGET* (92.5%) or *VALUE* (91.9%). However, applying a Wilcoxon-Rank-Sum test on the society level gives no significant differences between *BASELINE* and *BUDGET* (z=1.158, p=.2470), while there is a significant difference between *BASELINE* and *VALUE* (z=2.838, p=.0045). Note that all statistical tests to compare treatments are carried out by treating every society as one observation only.

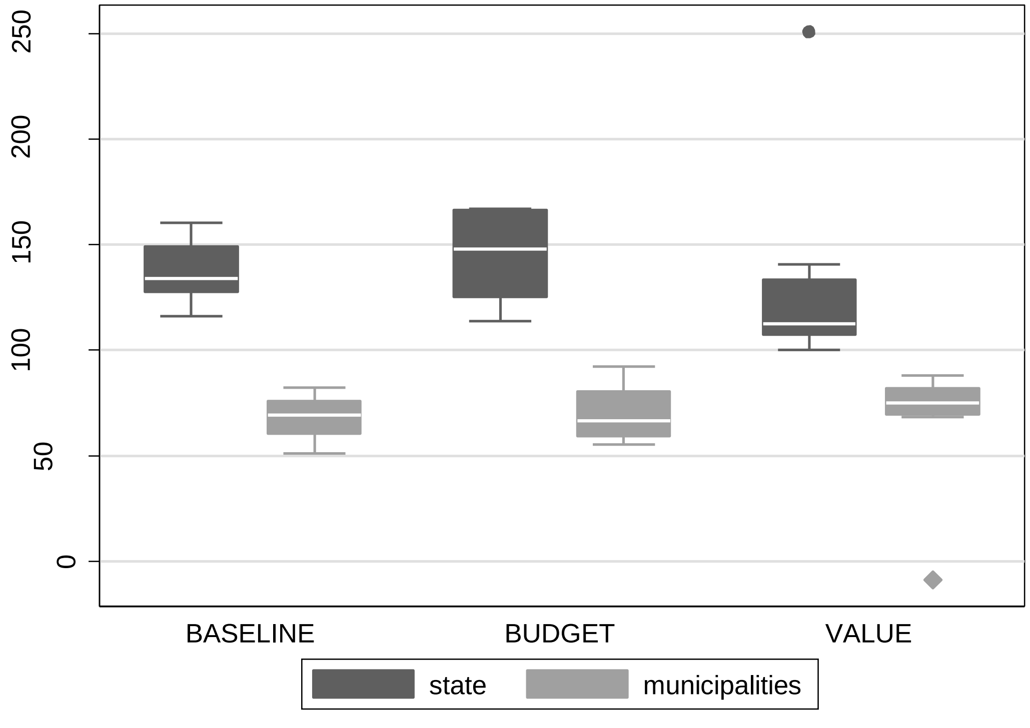
Result 1: *The reduction in land consumption can be achieved efficiently by a cap & trade system. It is largely resilient in terms of aggregate welfare for an uncertain macroeconomic environment.*

4.2 Distribution of income

Furthermore, we are interested in the distribution of aggregate welfare, i.e. the income distribution along municipality size and between the state and the municipalities.

Figure 4 presents state and municipality incomes in relation to the respective maximal achievable income, which gives a straightforward comparison of the state and the municipalities' aggregate income within societies.

Figure 4. Distribution of income between state and municipalities by treatment

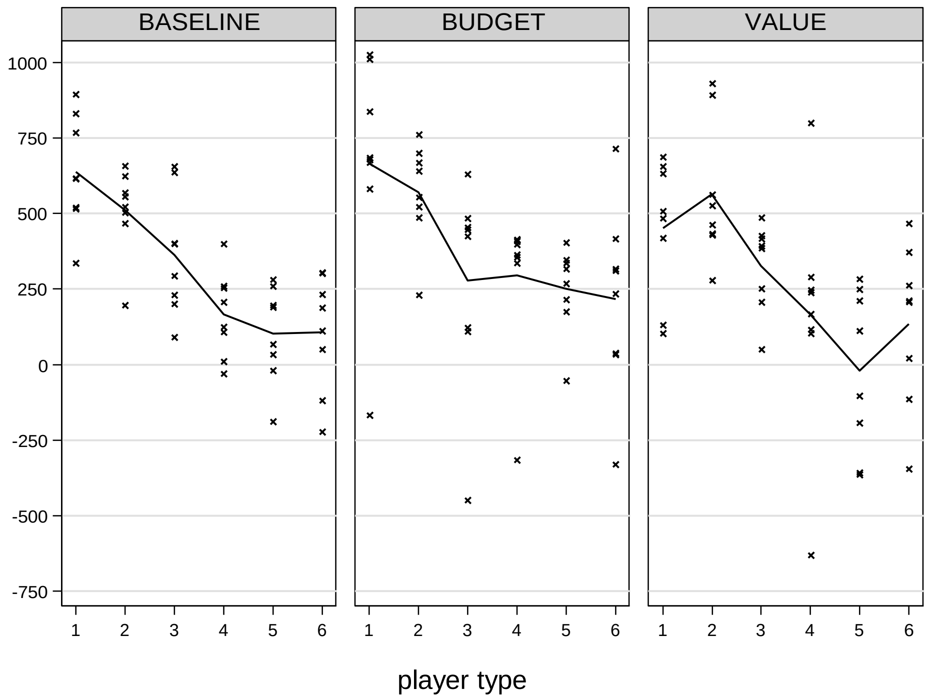


It can be seen that players fail to follow the payoff-maximizing strategy as the state's income exceeds the expected values for all treatments, while municipalities' aggregate incomes fall short of their maximum. For all treatments, the municipalities' exploitation of potential income is substantially lower than for the auctioneer, which clearly indicates that municipalities tend to overpay certificates in the auctions. Thus, municipalities systematically transfer income to the state and realize projects with a negative net value.

Result 2: *There is substantial bias in the distribution of income. The state as the auctioneer earns more than expected, while municipalities fail to realize their achievable income, thereby transferring a substantial share of their income to the state.*

Figure 5 presents municipalities' income by size and over treatments, whereby player type 1 is the largest municipality receiving four certificates per period, player type 2 the second largest endowed with three certificates, etc.

Figure 5. Distribution of income over player type by treatment



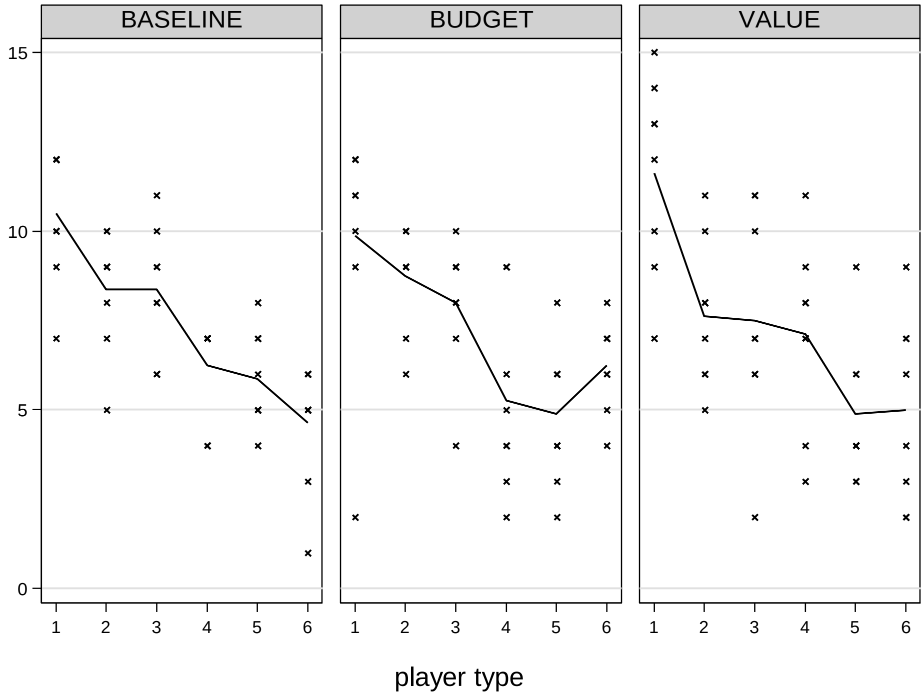
For all treatments, we find the expected pattern of net income decreasing in line with the number of certificates grandfathered per periods, i.e. in municipality size. In *BUDGET* and *VALUE*, the variation in net income conditional on player type tends to increase, as the shocks lead to a greater variance in the income distribution. There are more extreme values in the presence of exogenous shocks to the system.

Result 3: *An uncertain macroeconomic environment tends to increase the heterogeneity of municipalities' incomes, while the number of certificates received remains the crucial determinant of a municipality's income.*

4.3 Realization of outskirt development projects

Besides the distribution of income across municipalities, the distribution of realized projects should be considered, i.e. the question of whether the realization of Type A projects (simulating outskirt development) is influenced by the stability of the macroeconomic environment. The number of realized Type A projects conditional on player types over treatments is illustrated in Figure 6.

Figure 6. Distribution of realized projects over player type by treatment



We find the expected pattern as the number of realized Type A projects decreases along with municipality size, which is not substantially altered by our treatment conditions. However, the changes implemented in *VALUE* lead to more volatile results, which is consistent with our theoretical predictions.

Result 4: *The realization of outskirt development projects depends on the number of certificates grandfathered and the available projects. It is not substantially influenced by an uncertain macroeconomic environment, although the volatility of realized projects conditional on municipality size tends to increase in the presence of sudden reduction of building project values.*

4.4 Dynamics of prices

We consider the dynamics of prices as a crucial determinant of a cap & trade system's political feasibility. Municipalities rely on long-term planning processes, whereby uncertainty about certificate price developments might hinder the planning of land consumption projects in the first place. If municipalities with superior projects abstain from accumulating certificates and realizing projects due to this uncertainty, the system will fail to allocate land consumption projects efficiently. In particular, small municipalities that are grandfathered only few certificates might refrain from undertaking projects with an uncertain return, since these municipalities would have to spend a considerable share of their budget over many periods to accumulate certificates. Accordingly, both unit auction prices and market prices have to be assessed to evaluate the system's price dynamics, which is illustrated in Figures 7 and 8.

Figure 7. Dynamics of auction prices

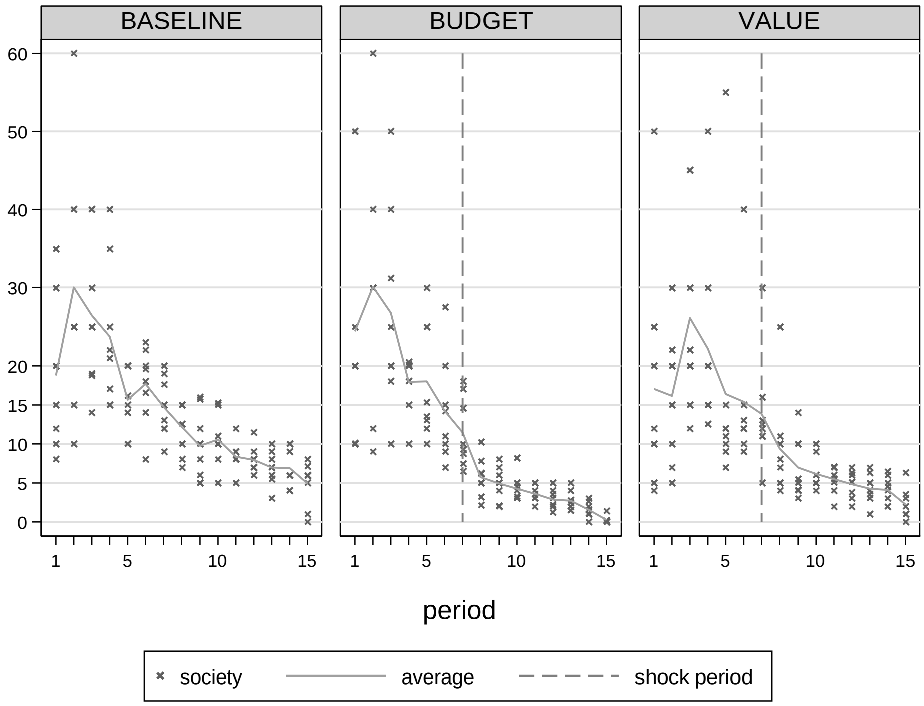
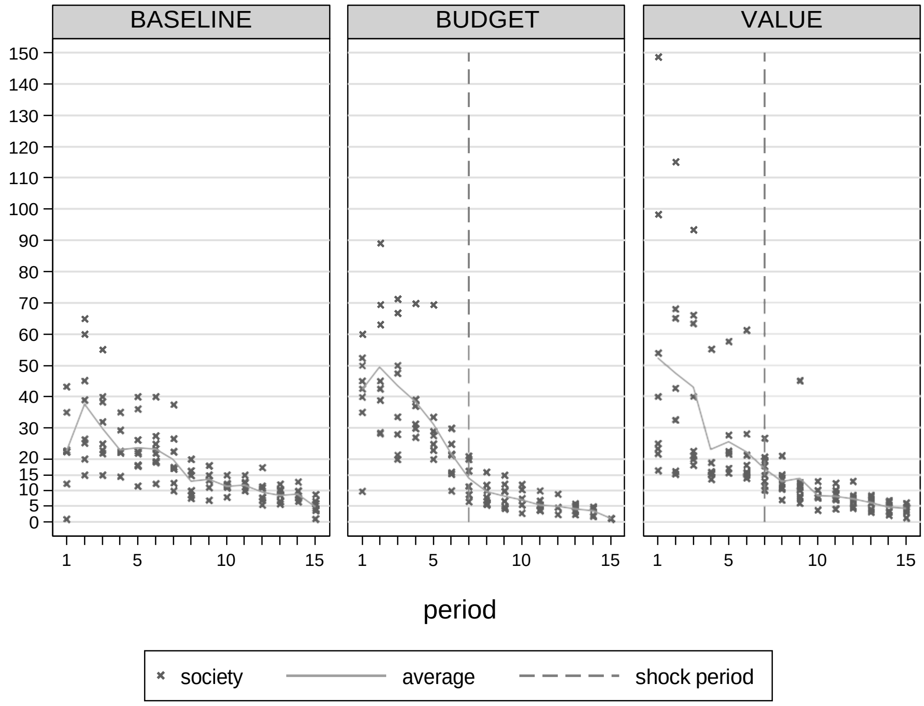


Figure 8. Dynamics of market prices



For unit auction and market prices, we find a similar basic pattern of prices exceeding fair values (11.25 ECU) in the beginning, as well as a subsequent decrease as the game proceeds. In the second half of the game, prices tend to be lower than the minimum expected prices. Unsurprisingly, the decreasing trend is strongest for *BUDGET* as subjects' lower endowment prevents higher prices. However, for all treatments, prices for the second half are significantly lower than in the first half (Wilcoxon-Signed-Rank test gives $p<.0117$).

Result 5: *Auction unit prices and market prices tend to decrease over the course of the game. While prices exceed fair values in the beginning, they tend to decrease below fair values at the end.*

A more detailed picture of price developments is provided by looking at price averages and standard deviations in the two halves of the game. Table 4 sums up the price developments and provides test statistics.

		BASELINE	*BUDGET*	*VALUE*
auction	period<=7	**20.99**	**20.41**	**18.14****
		(2.23)	(4.00)	(8.53)
	period >7	**8.43**	**3.21*****	**5.41*****
		(2.12)	(.79)	(1.06)
market	period<=7	**27.28**	**35.81**	**34.75**
		(7.14)	(14.63)	(22.12)
	period >7	**9.70**	**6.13*****	**8.5**
		(1.88)	(1.74)	(1.47)

Table 4. First and second half certificate price averages and standard deviations by treatment

Note: *, ** and *** indicate p-values smaller than 0.1, 0.05 and 0.01, respectively, which refer to tests against *BASELINE* applying a Wilcoxon-Rank-Sum test; standard deviation in parentheses. All calculations and tests are carried out on the society level.

As implemented in our experimental design and derived in the theoretical framework, the unit auction prices and average market prices in the exogenous shock treatments are lower than those in *BASELINE* in the second half of the game. This difference is higher for *BUDGET*. There seems to be no anticipation effect relating to the occurrence of the exogenous shocks as prices in the first half of the game are similar across treatments. However, the standard deviation of prices in the first half of the game indicates that the price volatility is higher for *BUDGET* and *VALUE*, whereas this relation is reversed in the second half of the game.

Result 6: *A macroeconomic environment with exogenous shocks has no effect on the level of auction or market prices in the pre-shock phase, yet increases price volatility. By contrast, in the post-shock phase, price levels and volatility are lower.*

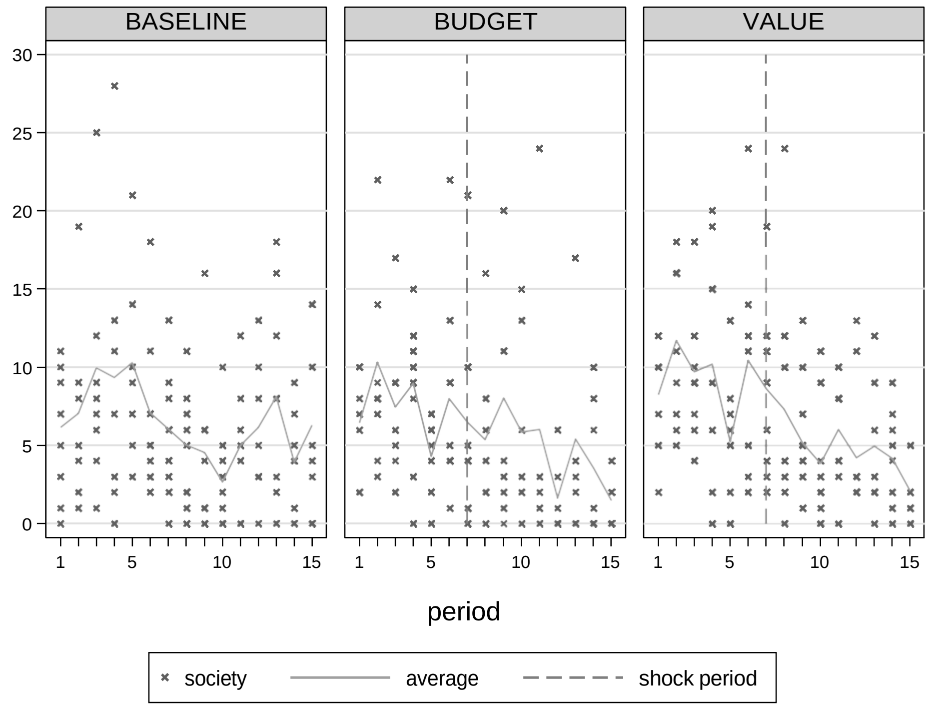
Furthermore, Table 4 shows that market prices exceed auction prices for the first and second half of the game in all treatments, whereby (except for the second half of *BASELINE*) differences are significant (Wilcoxon-Signed-Rank test gives $p<.0251$; for second half of *BASELINE* $p=.1235$). These differences are somewhat surprising and clearly violate assumptions of rational behavior since identical certificates are sold at different prices within the same period. Speculative opportunities open up, as subjects could buy certificates in the auctions at low prices and sell them at a substantial profit in the inter-municipality market. If this were the case, price differences should diminish over periods. However, the difference between unit auction and average market prices tend to be persistent as they amount to about 30%/75%/91% in *BASELINE*/*BUDGET*/*VALUE* for the first half and 15%/91%/57% for the second half of the game. These differences could be explained by the endowment effect (Kahneman et al., 1991). Accordingly, subjects ask for higher certificate prices on average when they own the certificates (willingness to accept an offer in the inter-municipality market) in comparison to their bidding prices for certificates they do not own (willingness to pay in the auctions). This systematic bias leads to the persistent gap in prices for all treatments.

Result 7: *Auction unit prices are substantially lower than average market prices. This is a systematic bias of individual decision-making that is explicable by the endowment effect.*

4.5 Dynamics of trading volumes

To assess the overall stability of the system, trading volumes can be assessed as an alternative indicator. Figure 9 illustrates average trading volumes in the inter-municipality market over periods by treatments.

Figure 9. Dynamics of market volume



The figure shows that for all treatments there is a downward trend in trading volumes (WSR-test gives p<.0684). However, there is no significant difference in overall trading volumes between *BASELINE* and any of the exogenous shock treatments (WRS-test gives p>.19).

Thus, subjects' propensity to engage in trading is neither negatively nor positively affected by the occurrence of macroeconomic shocks.

Result 8: *An uncertain macroeconomic environment does not affect certificate trading volumes.*

5. Discussion

How can these results be interpreted within the broader context of policy instruments to reduce land use? Obviously, an experimental approach to investigate a planned regulatory instrument has certain advantages, namely the ability to provide counterfactual analyses that can test the impact of changes to core parameters. That way, the effects of systematically different institutional designs can be assessed with a high internal validity, which can be seen as the core advantage of this methodology unattainable by normal field data analyses. At the same time, this approach also has certain disadvantages. Experimental studies require a certain degree of simplification of the complexities in a real-world situation to achieve a high level of internal validity. Consequently, not all aspects of the planned cap & trade system can be included in an experiment. Further, student participants may behave differently in an experimental setting than actual municipal decision-makers due to differences in training, experience and motivation. These aspects put restrictions on the direct applicability of our results. Nevertheless, particularly combined with field experiment including municipal actors, we are confident that experimental evidence can provide valuable insights on the optimal design for a cap & trade system for land consumption. Since field data can provide evidence for the reactions to external shocks only ex post, an experimental approach – despite its limitations – is the only empirical way to consider this highly relevant issue before introducing such a system.

On a basic behavioral level, our results can be summarized by stating that subjects – on average – behave fairly efficient with certain limits due to cognitive limitations and behavioral biases. The working mechanisms of the cap & trade system are understood fairly quickly by subjects and the individually payoff-maximizing choices are made, which also tends to maximize collective welfare. The failure to achieve the theoretical welfare levels can be attributed to cognitive limitations that separate actual persons from the omniscient theoretical benchmark player. Thus, overall, individual behavior leads to the collective result assumed by proponents of market-based mechanisms of reducing land consumption. These results resonate well with previous studies on market-based CO_2 certificates, which have provided similarly favorable results with regard to its effectiveness and efficiency (e.g. Grimm and Ilieva, 2013; Goeree et al., 2010). However, there is a distinct behavioral bias regarding individuals' biddings in the auction, which is unrelated to the exogenous shocks. Subjects show an irrational desire to gain certificates in the auction phase and fail to refrain from bidding overly high prices and buy at lower prices in the market phase, a behavioral pattern that can be explained as resulting from the endowment effect. This in turn leads to a substantial redistribution of payoffs to the auctioneer and reduces subjects' aggregate payoffs.

More generally, our results suggest that a cap & trade system successfully compensates exogenous shocks. Despite substantial changes to the basic parameters of the system resulting from the macroeconomic shocks, only small reductions in overall welfare occur. Whether inner-city rather than outskirt development is executed continues to be determined by municipality size and the number of certificates grandfathered. While municipalities' incomes become more heterogeneous following a shock, the number of certificates received also continues to be the central determinant of a municipality's income. Similarly, auction and trading prices are somewhat more volatile before the shock, yet volatility and price levels tend to decrease over the course of the game and do not substantially affect trading volumes. Overall, we find that the cap & trade system proves resilient against macroeconomic disturbances. Despite being unrelated to our shock treatments, a major problem observable is the divergence of auction and market prices, which leads to a substantial income redistribution to the federal state. Due to the persistently higher auction prices, which are not reduced by speculation motives, municipalities forego a substantial share of their potential income.

In terms of policy-making, this redistribution of incomes is likely to be a critical issue for municipalities fearing excessive financial transfers to the federal state due to the specific auction design. Obviously, this potential disturbance to the functioning and political feasibility of a cap & trade system should lead to additional concern regarding the exact design of both the auction and the market mechanisms. However, our core policy contribution is that a cap & trade system for land consumption as planned by German regulators can be considered fairly robust against macroeconomic shocks. Despite the limitations of laboratory experiments, our results emphasize the flexibility of a market setting and its resilience against shocks. Accordingly, the flexibility of market-based cap & trade system in allocating permissions to use land to municipalities despite shocks connected to economic and budgetary crises makes it a preferable policy choice when compared to more static regulations on land consumption by central states. Providing a market-based instrument for reducing and controlling land consumption can thus help regulators to cope flexibly with the challenges posed by economic crises and financial shortcomings of municipalities.

How can these results be transferred to other contexts apart from the specific German case? In this regard, particularly the connection to the concept of transferable development rights (TDR) in the United States can be fruitful. Within the United States, a large number of local programs have implemented tradable development rights with a fairly heterogeneous institutional design (Pruetz, 1997; Pruetz and Standridge, 2008). Since we implement a rather general setting, core parts of our research design are similar to the existing American programs. We would therefore argue that the research on factors of success of TDR schemes (see e.g. Harman et al., 2015) can be enriched by our experimental approach. Particularly since empirical evaluations of the working mechanisms are still rare (Kaplowitz et al., 2008; Bengston et al., 2004), experimental evidence can provide additional behavioral insights. Our results on the resilience in the face of macroeconomic shocks can thus add empirical evidence that can help improve the design of TDR schemes worldwide, despite the heterogeneity of its implementation.

6. Conclusion

In this study, we present experimental results on the resilience of a cap & trade system for land consumption projects when confronted with macroeconomic instability. We extend the primarily theoretical literature on tradable planning permits as a means of reducing land consumption by providing empirical evidence generated in a controlled laboratory study. Accordingly, we implement treatment conditions that simulate the impact of two of the most relevant influences affecting municipalities, i.e. external shocks resulting in the reduction of demand on land consumption as projects' profitability decreases, as well as income shocks resulting in budgetary cuts. We assess individual and overall market reactions to these exogenous shocks. If a cap & trade system for land consumption certificates would not prove robust against such exogenous shocks, its political feasibility would be questionable. Our findings contribute to the discussions on a cap & trade system and provide evidence on actual behavior within these systems, which can complement theoretical modelling. Overall, the market-based system successfully compensates shocks without major welfare losses. Price volatility increases prior to shocks, yet normalize subsequently; trading volumes and project realizations are unaffected by the shocks. We can thus conclude that the introduction of a certificate scheme is supported by our experimental results since it proves resilient under macroeconomic instability.

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Appendix: Instructions for the three treatments. Differences in treatments are indicated in brackets.

OVERVIEW OF THE GAME

You can earn money in this game by realizing projects and trade with certificates. At the beginning, you will be randomly assigned to a group of 6 players, which will remain constant during the 15 periods of the game. All prices and values in the game will be paid in ECU with up to two positions after decimal point. 100 ECU convert to 1€ for your payoff.

Projects

Overall, each player has 30 projects of **Type A** and 15 projects of **Type B**. Both types of projects have different values, which are shown in this table:

Type of project	Projectvalue (in ECU)
A	0 bis 100
B	10

In each period, only one project can be realized. Before the game starts, the values of all Type A projects will be assigned shown to you. All players are assigned different Type A projects.

Certificates

For the realization of Type A projects, you need 8 certificates each, Type B projects do not require certificates. Certificates are assigned to you at the beginning of each period and auctioned. Additionally, certificates can be traded among the players. In the game, you receive an endowment of 700 ECU which you can use to buy certificates at the auction and from the other players. You can also sell certificates and thus increase your payoff.
{T2: **Please note**: In a period unknown to you, the value of all players' projects will change. After this period, all projects have a different profitability for the rest of the game.}
{T3: **Please note**: In a period unknown to you, all players' funds will **only once** be frozen and exchanged for another amount of ECU. Your "frozen" funds will be returned to your at the end of the game; however, you cannot use it anymore from the respective period onwards.}

Your payoff

The payoffs you receive in the course of the game, as well as the sum of all realized projects add up to your final payoff. Further, a basic payoff of 400 ECU will be added.

COURSE OF THE GAME

Each of the 15 periods follows an identical course, which consists of three phases.

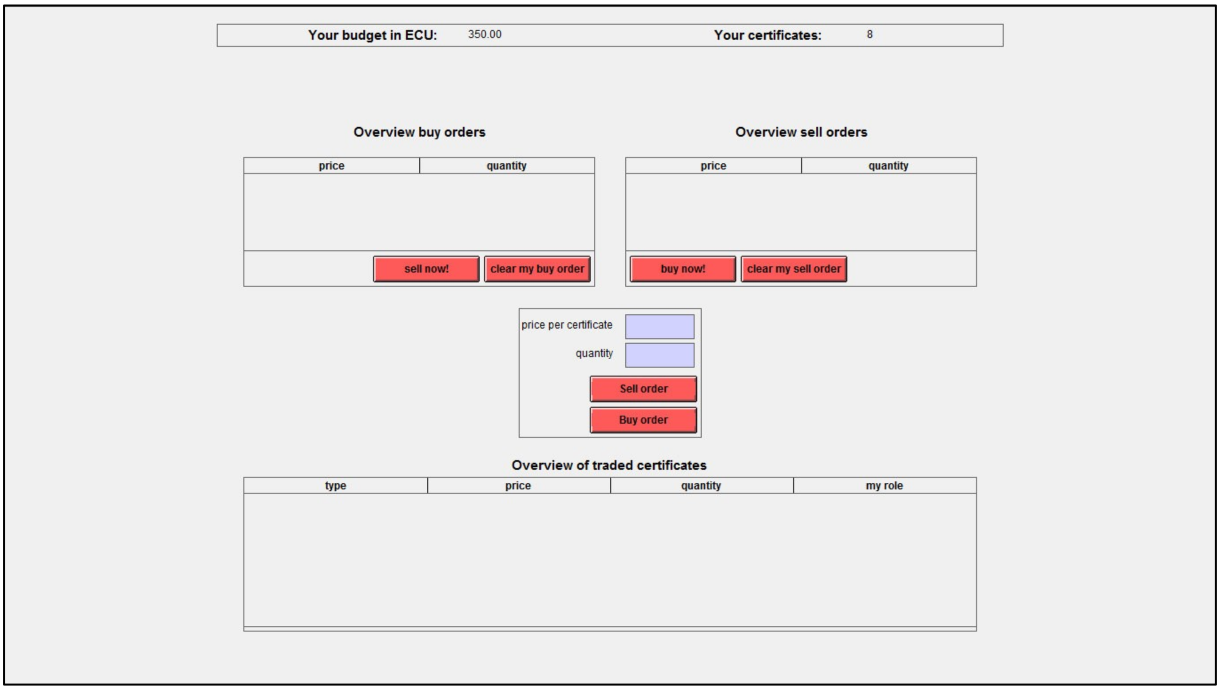
Phase 1: Allocation and auctioning of certificates

At the beginning of each period, 12 certificates are allocated. The number of certificates a player receives is determined randomly at the beginning of the game and does not change during the game.

Additionally, after the allocation, 12 certificates are auctioned. Depending on your current funds, you can bid for a number of certificates of your choosing at a unitary price. The 12 highest bids will receive the certificates to the price of the lowest successful bid.

Phase 2: Trading of certificates

Following the allocation and auctioning, this phase lets you trade with the other five players, i.e. buy and sell certificates. You can offer a trade yourself and also accept offers from other players. To clarify this, you see the respective screen of the trading phase below:



Offering a trade

In the lower box, you can enter a price (in ECU) and the respective amount of certificates that you would like to buy.

- **By clicking "searching"**, all players are shown your buying desire in the left box. Once another player agrees to your offer, you will receive the respective number of certificates. The total value (price x quantity) of the trade will be withdrawn from your funds.
- **By clicking "offering"**, all players are shown your sell offer in the box on the right. Once another player accepts your offer, you sell the respective number of certificates. The total value (price x quantity) of the trade will be added to your funds.

Accepting another player's offer

In the boxes on the right and left side, you can see all current buy and sell offers for certificates. If you choose an offer and click on "sell now!" or "buy now!", you make the trade with the respective player.

You are allowed to trade as often as you please. You can also make multiple sell and buy offers at the same time. The trading phase ends automatically once **2 minutes** have passed.

Phase 3: Realizing projects

In the third phase of the game, you can realize one of your projects. You will receive the respective payoffs (project value in ECU) at the end of the game. After the third phase, the next period begins. Certificates that are not used in one period can be saved for subsequent periods. Note, however, that you will not receive a payoff for certificates that remain unused until the end of period 15!

Workingpaper Nr. 3

THE POLITICAL ECONOMY OF CERTIFICATES FOR LAND USE IN GERMANY – EXPERIMENTAL EVIDENCE

von

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The political economy of certificates for land use in Germany – experimental evidence

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Abstract: Certificate trading schemes have been discussed as a cost-efficient means of reducing land use in Germany by capping and reallocating permissions to conduct building projects. However, in contrast to the established cap & trade systems for emissions, reputation-seeking politicians would be in charge of buying and trading certificates – an aspect not considered to date. We thus present a laboratory experiment that captures politician's incentives connected to electoral cycles in a cap & trade scheme for land use, whereby tradable certificates are auctioned and grandfathered in equal shares. We find the cap & trade system to be efficient at large, yet there are several politically relevant distortions that are aggravated by self-serving incentives. Prices show high volatility, initially by far exceed fair values and are substantially biased by the endowment effect. Further, the timing and location of land use projects and the heterogeneity in income across municipalities are sensitive to the specifics of the system and politicians' interests. We thus identify potential problems to a cap & trade system for land use that could substantially reduce both its assumed superior efficiency and its political feasibility.

Keywords: economic experiment, land use, municipal actors, political business cycle, tradable certificates

JEL Classification: C910, Q580

I. Introduction

Increasing land use and degradation due to economic activity has been recognized by industrialized nations as a core obstacle to the preservation of natural resources and biodiversity. Consequently, economic and environmental policy-makers are striving for effective means to preserve biodiversity and ecologically valuable land while sustaining economic growth (Fischer et al., 2013; Weber, 2006). To achieve these goals in Germany, in 2002 the federal government committed to taking measures to reduce the growth of settlement and traffic infrastructure from the 81ha per day in 2008-2011 (Federal Statistical Office, 2013) to 30ha by 2020 (Federal Government, 2002). This political commitment was confirmed by the latest German coalition treaty of 2013[1] and has revived the scientific discussions on regulatory measures to reduce land use.

While the traditional approach to reducing land use demands stricter regulatory planning control over all administrative levels or increased taxation (Bovet et al., 2011), environmental economists have been calling for more efficient policy instruments (Hansjuergens and Schroeter-Schlaack, 2008). A strand of literature emerged considering the introduction of tradable certificates systems as a presumably superior instrument for reducing land use.[2] This superiority is assumed to stem from market forces achieving a nation-wide reallocation of the limited number of certificates to the most valuable land use projects. The market system is thus expected to allocate certificates efficiently among political entities, in the German case municipalities (Henger and Bizer, 2010). Conversely, a centrally administered allocation of land use permissions is expected to fail in minimizing welfare losses following a cap on land use (Henger, 2010).

Several arguments are presented in support tradable certificates for land use that mirror the arguments for CO_2 cap & trade systems. Primarily, the cap & trade system is expected to allow for the realization of the most valuable projects at minimal transaction costs (Hansjuergens and Schroeter-Schlaack, 2008). Secondly, the superior precision of the

[1] Coalition treaty between the conservatives (CDU/CSU) and socialists (SPD), see Coalition Treaty (2013), p.83.

[2] The discussion in Germany has been driven by numerous studies issued by governmental agencies following the federal government's 2002 commitment. Among the recent studies are Walz et al. (2005) for the Federal Ministry for the Environment, the Council of experts on environmental questions (2002), Heiland et al. (2006), Perner and Thoene (2007), Bizer et al. (2012) for the Federal Agency for the Environmental Protection, as well as Kaule and Siedentrop (2010). Evolving simultaneously, the scientific discourse has put forth a large number of publications from the perspective of institutional and environmental economics concerning its practical and theoretical questions, which can be accessed through the recent dissertations by Schroeter-Schlaak (2013) and Henger (2010).

mechanism implementing a fix quantity and variable prices is pointed out, which is unattainable through a centrally administered regulation of prices. Thirdly, a cap & trade system inherently provides incentives for decision-makers to use land more efficiently, thus stimulating innovative inner-city development (Schmalholz, 2005) rather than continuing to rely on the use of undeveloped outskirt areas (Wegelin, 2006). Fourthly, the participation in the trading scheme is likely to increase municipal awareness of the ecological problems of land use (Henger, 2010).

To empirically assess these mostly theory based claims, two framed field experiments have been presented to provide empirical evidence, both featuring municipal officials interacting in a realistic system of allocation and trading of certificates (Ostertag et al., 2010; Henger, 2011; Henger 2013). They find the trading system to work fairly efficient overall. However, both experimental designs implement a payoff function that assumes municipal politicians to unambiguously strive for the maximal outcome for their community by optimally weighing costs of certificates and the return of land use projects. While assuming such an optimization behavior in the case of strictly profit-maximizing companies buying CO_2 certificates may be appropriate[3], we argue that in actual municipalities, the politicians' and the collective interest frequently diverge. Our argument is motivated by the established evidence in public choice emphasizing that politicians tend to consider their individual payoff rather than maximizing the welfare for their constituents (Black, 1948; Downs, 1957). This regularly translates to starting "political business cycles" (Nordhaus, 1975; Buchanan and Wagner, 1977) through increasing public spending before elections. In turn, short-sighted spending policies due to the individualistic time preference contradict macroeconomic stability and long-term fiscal prudence (e.g. Buchanan and Tullock, 1962). Following these seminal contributions, a large number of empirical studies have confirmed this characteristic pattern of public spending prior to elections (for a recent survey, see Eslava, 2010) with several studies suggesting that

[3] While empirical studies on land use certificates remain limited, a large body of empirical literature has evolved dealing with various aspects of CO_2 emission certificates, particularly regarding the European emissions trading system in 2005, to which Convery (2009) provides an introduction. Furthermore, numerous experimental studies have investigated various aspects of certificate allocation trading schemes, including the efficiency of different allocation mechanisms (Grimm and Ilieva, 2013); the effect of market power of participants (Cason et al., 2003); price discovery in emissions certificate auctions (Burtraw et al., 2010); collusion and speculation in emission certificate markets (Mougeot et al., 2011) or different pricing strategies following an initial allocation of certificates (Wrake et al., 2010). While these studies enable a substantiated prediction of the behavior by profit-maximizing entities in a certificate-trading situation, they offer no outlook on potential distortions caused by reputation-seeking political actors.

politicians on the municipal level act similarly.[4] Accordingly, politicians in a cap & trade system for land use could start political business cycles by purchasing certificates to conduct specific projects prior to elections to increase their chance of reelection while potentially concealing that the costs for certificates are higher than the expected return of the land use projects. Different from a traditional regulatory cap on land use, politicians in a cap & trade system might be susceptible to short term individual gains translating into long term collective losses. This systematic distortion might reduce the theoretically assumed superiority of a cap & trade system, and thus needs to be taken into account when assessing its efficiency and political feasibility.

To investigate the distortive influence of self-serving politicians, laboratory experiments provide a methodology that allows us to run a counterfactual comparison of different institutional settings, which remains inaccessible when using field data.[5] While experiments might have a lower external validity, they enable us to highlight the effects of systematically different incentives and individually biased reactions, both of which are accessible only in counterfactual ceteris paribus analyses. As our experimental design comprehends the main features of a cap & trade scheme in land use, we are confident that our results can provide novel insight on potential distortions and hold external validity. Accordingly, we present an experimental design that implements self-serving motives for politicians trying to maximize their electoral success by authorizing and conducting specific land use projects, which potentially reduce the respective municipality's and overall welfare. Our experiment implements a cap & trade system that is structured according to the current state of discussion within the German administration. Six players each simulate a municipality and generate income by realizing projects over the course of the game. Project realizations are restricted by the total number of certificates available, whereby in the first stage of each period half of the

[4] Prime examples of such studies concerning overall municipal expenditures prior to elections include Goeminne and Smolders (2014) for Flemish municipalities, Alesina and Paradisi (2014) for Italy, Bastida et al. (2013) for Spain, Sakurai and Menezes-Filho (2011) for Brazil, as well as Veiga and Veiga (2007a) and Coelho et al. (2006) for Portugal and Foucault et al. (2008) for France. More specifically, Klien (2014) points to a similar result for local water tariffs in Austria, while Guillamon et al. (2013) show the effect or municipal police expenditures in Spain. Vicente et al. (2013) show a strong relationship between transparency in municipal governments and the level of pre-electoral spending. Veiga and Veiga (2007b) point out that the likelihood of reelection is highest for incumbents when spending on highly visible items is increased, particularly on building projects.

[5] For example Sutter (2003) and Tyszler (2008) have provided initial evidence suggesting that the relationship between opportunistic behavior by political actors and election dates is robust in a laboratory setting.

certificates are grandfathered and the other half is sold in a uniform price auction with sealed bids. In the subsequent second stage, certificates can be traded in a double auction market. In the third and last stage subjects may execute their projects provided that they have collected enough certificates. These features apply to our benchmark treatment, whereby the reputation element is added in a second and third treatment, which both feature electoral cycles and a substantial bonus payment representing politician's benefit of an increased reelection probability. In the second treatment the bonus is achieved by realizing a prestigious project. In the third treatment, subjects can signal activity and competency and thus achieve the bonus by completing a player-specific number of projects prior to the election period; however, there are not enough certificates available to allow all subjects to obtain the bonus. We are interested in whether politicians seeking to increase their likelihood of reelection, i.e. striving for the bonus, may lead to a substantial decrease in the efficiency and stability of a cap & trade system for land use. This would have stark political implications for the feasibility of this mechanism to reduce land use.

The remainder of this paper is organized as follows. In section 2, we explain the experimental design; Section 3 provides a theoretical framework. Section 4 presents our results and section 5 concludes.

II. Experimental Design

We outline our experiment in five steps. First, we describe the general course of the game, before secondly explaining player and projects specifics. Third, we present the payoff regime and, fourthly, we describe our treatment conditions and provide information on the experimental procedure. A theoretical framework deriving the individual and collective payoff-maximizing behavior is detailed in section 5.

Course of the game

We implement a 15-period three-stage game that closely simulates the issuing and trading of certificates for land use as outlined in studies for the German Federal Environmental Agency and implemented in previous field experiments (Ostertag et al., 2010; Henger, 2011). Although framed neutrally, subjects represent municipalities obliged to accumulate certificates to realize land use projects. Three stages in each period capture the accumulation, trading and consumption of certificates.

In the first stage, subjects accumulate certificates to realize land use projects later on. 50 % of certificates are issued through a uniform price auction with sealed bids, where bidders enter a quantity and price. The bids are then ranked and the price for the least unit that is auctioned determines the unit price that all bidders have to pay for their respective quantities. The remaining 50% of certificates are grandfathered, i.e. they are issued to subjects for free. Overall, 12 certificates are grandfathered and an additional 12 certificates auctioned in each period.

The second stage enables subjects to trade certificates in a double auction market for two minutes. There are no limits on prices or quantities and no transaction costs. Accordingly, subjects can generate income by selling certificates or they can buy additional certificates from other players.

The third stage involves players using their certificates on land use projects that yield income conditional upon the respective project values. Each player can only realize one project per period. Unused certificates can be accumulated over periods but expire after the last period without compensation.

Player and project specifics

We employ a partner matching protocol as subjects are randomly assigned to societies of six at the beginning of the game. Within all societies, each of the six subjects is assigned a specific player type to capture different sizes of administrative units. Subjects are endowed with a player type-specific pool of 30 projects.

There are two types of projects, denominated as “Type A” or “Type B”. The former require eight certificates for realization, simulating projects with a high land use outside of urban areas, which the cap & trade system would aim at reducing. Type B projects do not require certificates, simulating inner-city development, which – despite being more costly than development in the outskirts - is considered as an ecologically preferable alternative. Note that we assume all Type A projects to use up the same quantity of land as they require the same number of certificates. While this represents a strong simplification, it serves at keeping the game comprehensible to participants without violating the basic characteristics of a cap & trade system. Type A projects pay at most 100 experimental currency units (ECU), decreasing in five steps of 20 to zero ECU, while Type B projects always pay 10 ECU.

Player types representing larger municipalities are assigned more valuable projects, which captures the extended possibilities associated with a greater size of the municipalities. Furthermore, player types are grandfathered a different number of certificates, simulating the apportionment of certificates according to the population of administrative units. Players are not informed about other player types’ number of grandfathered certificates or their available projects; they merely know that all of them have Type A projects worth 0 to 100 ECU and Type B projects paying 10 ECU.

Table 1 provides an overview of player types, as well as their assigned number of certificates and available projects.

project	**Number**	1	2	3	4	5	6	7			
	Value	100	80	60	40	20	0	10			
	type	A	A	A	A	A	A	B			
	certificates	8	8	8	8	8	8	0			
player										**certificates period (total)**	
	#projects for type								**total**	#grandfathered	#auctioned
	1	10	8	6	4	2	0	15	**45**	4(60)	-
	2	8	10	6	4	2	0	15	**45**	3(45)	-
	3	6	8	10	4	2	0	15	**45**	2(30)	-
	4	4	6	8	10	2	0	15	**45**	1(15)	-
	5	2	4	6	8	10	0	15	**45**	1(15)	-
	6	0	2	4	6	8	10	15	**45**	1(15)	-
	total	**30**	**38**	**40**	**36**	**26**	**10**	**90**	**270**	**12(180)**	**12(180)**

Table 1. Overview of players, projects and certificates

Payoff structure

A subject’s payoff of the game comprises three parts: (1) the initial endowment, (2) the net payments for certificates and (3) the revenues generated by the realization of projects. All payoffs, prices and values of projects are denoted in ECU, whereby 100 ECU convert to 1€ at the end of the game.

The initial endowment of 700 ECU enables players to participate in the auction and trading stage. It decreases as certificates are purchased in the auctions or the trading stages and it conversely increases when certificates are sold to other players. Subjects’ current budgets constrain potential buying offers or biddings in auctions, so there is no borrowing from the experimenter. The revenues from realized projects are paid at the end of the game to simulate the long-term character of land use projects and the delay of potential returns for municipalities. Additionally, players receive a show-up fee of 4€ unrelated to the game itself.

Treatment conditions

A benchmark treatment (*BASELINE*) incorporating all specifications as described above is run to assess the efficiency of a cap & trade system for land use in general, as well as serving as a benchmark for the treatments outlined below.

We are interested in the effects of introducing self-serving motives for municipal decision-makers. In line with previous studies in public choice, we assume that political actors’ aim for reelection is a central influence in their individual utility maximization (Black, 1948; Downs, 1957). Given that politicians often try to influence reelections through the visible realization of specific projects (Veiga and Veiga, 2007), we hypothesize that the politically motivated pursuit of higher reputation will influence the efficiency of a cap & trade system for land use. In this case, it might be profitable for politicians to realize particular projects at a specific point in time, thus condoning long-term disadvantages for their community due to political business cycles. As the costs for land use certificates might be disguised from the electorate, bearing excessive costs that cannot be balanced by gains from project realizations might be optimal for politicians, given that these project realizations increase the probability of reelection. By contrast, municipalities' overall welfare depends on the relation of actual gains from realized projects and the net payments for certificates.

By introducing two treatment conditions, we aim to analyze the effects of such scenarios on the overall efficiency, prices and the distribution of income in a cap & trade system for land use.

(I) Realization of a prestigious project prior to an election (PRESTIGE)

Our first treatment condition implements a rather weak incentive for starting political business cycles. We assume that politicians can increase the probability of reelection by carrying out a prestigious project right before the election date that adds to her reputation. In our design, this transfers to a bonus payment of 300 ECU if a subject manages to realize one of her most valuable projects specifically in period 7.[6] While we explicitly chose non-extreme values for the bonus, it remains sufficiently high to divide municipalities and politicians' welfare to a relevant extent. Besides the bonus payment, all other parameters of the general setting apply. The manipulation in *PRESTIGE* can be seen as rather mild as all players are able to realize the bonus payment simultaneously and the overall efficiency should not be affected. For considerations of altered optimal behavior for players in both treatments and the respective implications, we refer to section 3.

(II) Showing competency and high activity before and election (ACTIVITY)

In our second treatment, we implement a more competitive structure of obtaining the bonus payment of 300 ECU. Again, the game up to period 7 simulates the pre-election phase. Subjects are now required to display a high level of activity to achieve the bonus, again representing the increased probability of reelection through higher reputation. This level of activity is defined by a certain number of projects to be realized. The respective number of projects required is determined conditional upon a municipality's size, i.e. on player types.

[6] For reasons of simplification, we only consider the case of simultaneous elections, which is also the appropriate setting when looking at German municipalities within a federal state.

Players 1 to 6 require 6/5/4/3/3/3 realized projects for the bonus and thus necessarily need to buy additional certificates. It should be noted that it is not possible for all players within a society to earn the bonus at the same time in this treatment, due to the restricted total number of certificates available. Therefore, it can be expected that changes in prices and overall efficiency are stronger in *ACTIVITY* than in *PRESTIGE*, which is again explained in further detail in section 3.

Procedure

Treatment	**bonus activity**	**bonus prestige**	**No. of participants**	**No. of societies**
Baseline	no	no	48	8
Prestige	no	yes	48	8
Activity	yes	no	48	8
total			**144**	**24**

Table 2. Summary of treatments and participants

Table 2 provides an overview of our treatments, variations and the respective numbers of participants. The experiments took place in 11 sessions within one week in October 2014. They were run with z-Tree (Fischbacher, 2007) in the Laboratory for Behavioral Economics at the University of Goettingen; the participants were recruited with ORSEE (Greiner 2004). They were only allowed to participate in one session and the understanding of the game was guaranteed by asking mandatory control questions before the experiment started. The sessions in all treatments lasted around 80 minutes. There were 48/48/48 participants in *BASELINE/ACTIVITY/PRESTIGE*. On average, each participant earned 15.65€. Participants were students from various fields (49% economic sciences as the largest group), were 24.4 years old on average and 50% were female.[7]

III. A theoretical framework

Without a cap on land use, players will activate their 15 most valuable projects of Type A (see Table 1). In this scenario, a total of 90 land use projects would be realized. We assume the state (federal government) to aim at reducing land use by 50% to foster inner-city development using a cap & trade system. Consequently, the regulatory cap only allows for three projects per period, a total of 45 Type A projects and 45 Type B projects over the course of the game. As we assume all Type A projects to lead to the same land use and uniformly

[7] The original instructions for the game were in German. They are available from the authors upon request; a translation is provided in Appendix A.

require eight certificates, this determines the total number of certificates issued per period to be (3 x 8) 24 certificates.

We rely on the willingness to pay to calculate the equilibrium prices for certificates. A player deciding to realize a Type A project bears opportunity costs of 10 ECU, i.e. the fixed value of Type B projects. The realization of the most valuable Type A project pays 100 ECU and requires eight certificates. The willingness to pay for one certificate then amounts to (100-10)/8=11.25 ECU. Overall, there are only 30 projects with a value of 100 ECU, which players do not know. Therefore, players act rationally if they are willing to pay 11.25 ECU per certificate as long as Type A projects worth 100 ECU are available. Subsequently, prices should drop to (80-10)/8=8.75 ECU. A rational player sells certificates if prices exceed the fair price and buys if they are lower. Players have all the information to derive these fair prices for certificates.

Consequently, the prices observed in *BASELINE* should not exceed these fair values. It cannot be stated unambiguously which projects worth 80 ECU will be realized, given that several players have the same willingness to pay. To illustrate a potential outcome, we assume that the certificates will be allocated according to players in descending order. For payments in the auction and the market, we assume that players pay the full 11.25 ECU for certificates used for Type A projects and 8.75 ECU for Type B projects and grandfathered certificates are distributed evenly between 100 ECU and 80 ECU projects.[8] Table 3 details the resulting project realizations and welfare effects. Please note that "net transfer" simultaneously measures the income of the state as auctioneer, since all certificates bought were initially sold by the state in the auction.

[8] For example, player 1 realizes ten 100 ECU projects and five 80 ECU projects and is grandfathered 60 certificates. We then assume that she uses two thirds of these grandfathered certificates for 100 ECU projects and one third for 80 ECU projects. Accordingly, the 60 certificates she has to buy additionally raise costs of 40 certificates at 11.25 ECU and 20 certificates at 8.75 ECU.

project	**number**	1	2	7						
	value	100	80	10						
	type	A	A	B						
	certificates	8	8	0						
player						**certificates total**		**value**		
	#projects for type				**total**	#used	#bought(free)	gross	net transfer	net
	1	10	5	0	**15**	120	60(60)	1400	625	775
	2	8	5	2	**15**	104	59(45)	1220	607	613
	3	6	5	4	**15**	88	58(30)	1040	587	453
	4	4	0	11	**15**	32	17(15)	510	191	319
	5	2	0	13	**15**	16	1(15)	330	11	319
	6	0	0	15	**15**	0	-15(15)	150	-157	307
	total	**30**	**15**	**45**	**90**	**360**	**180(180)**	**4650**	**1864**	**2786**
	value	**3000**	**1200**	**450**						
	certificates	**240**	**120**	**0**						

Table 3. Potential project realizations in BASELINE and PRESTIGE

Note: All numbers are rounded to integers. “free” refers to certificates grandfathered.

It can be seen that there should be 45 project realizations of Type A (30 worth 100 ECU and 15 worth 80 ECU) and 45 realizations of Type B, which represents the most efficient solution to achieve the regulatory objective of halving land use. Players’ income subsequently depends on the projects available and certificates grandfathered. The net transfer describes the maximum income of the state given perfect price discrimination fully transforming consumer (player) surplus to revenues for the auctioneer.

Note that payments in the auction can be seen as a mere matter of transferring wealth to the state; payments in the market stage redistribute wealth among municipalities. In this system, inefficiencies can only occur due to unused certificates or inferior project realizations.

Rationality in PRESTIGE

In *PRESTIGE*, players need to accumulate eight certificates in period 7 to earn an additional 300 ECU. Players 4 to 6 are only grandfathered seven certificates until period 7 but can buy one additional certificate at 11.25 ECU or with a marginal surplus. Assuming payoff maximizing behavior, the overall effect on prices should be negligible, overall efficiency should remain constant and all players should obtain the bonus by uniformly realizing the most valuable project at the same point in time (right before the election date).

However, we are interested in whether this slight manipulation of incentives for actual players causes politically relevant distortions in a cap & trade system, such as increased price volatility or substantial income redistributions.

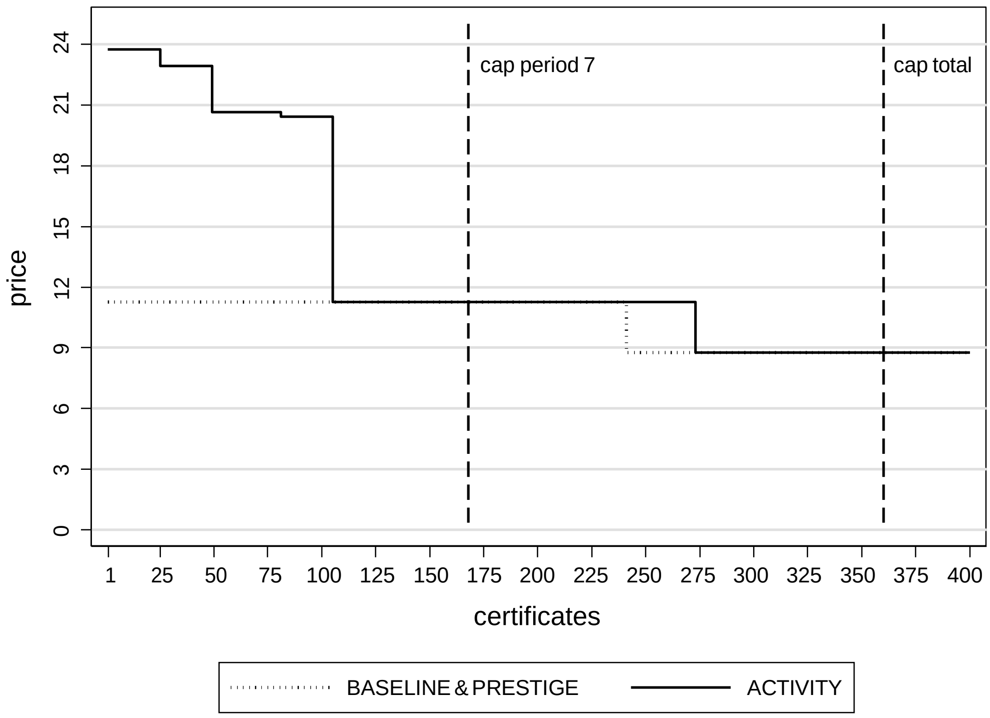
Rationality in ACTIVITY

While no significant reaction should be observed in *PRESTIGE* assuming rational agents, *ACTIVITY* introduces a much more effective shift of incentives. As mentioned above, not all players can simultaneously realize the number of Type A projects required to obtain the bonus payment since not enough certificates are issued.[9] Besides, the dynamics of the game, e.g. the one project per period restriction, have to be considered as a potentially restrictive criterion.

The willingness to pay for certificates in the *ACTIVITY* condition is different for each player due to the bonus payment requirement, whereby the smaller municipalities tend to be willing to pay more per certificate.[10] Primarily the players with a higher willingness to pay will accumulate the required number of certificates and thus obtain the bonus.

Figure 1 shows the aggregate demand and the respective equilibrium prices over all treatments.

Figure 1. Aggregate demand function for certificates by treatment



[9] Overall, 24 projects need to be realized until period 7, while the restriction to 24 certificates per period also restricts the maximal number of projects to [(24/8)*7=] 21.

[10] Mean willingness to pay represents the average payoff a player can obtain with a certificate and depends on the available projects and the number of certificates needed to obtain the bonus. E.g. for player 1, we calculate the mean willingness to pay as:

[(# required Type A*(net value Type A) + bonus) / required certificates]=[(6*(100-10)+300)/48] =17.5 ECU.

In *ACTIVITY*, players foregoing the bonus should be compensated by benefitting from higher certificate prices. In Period 5, once 104 certificates are accumulated by the players achieving the bonus payment (players 3 to 6), prices should drop to fair values derived merely by the remaining projects. Table 4 summarizes project realizations that lead to the bonus payment derived from aggregate demand.

project	**number**	1	2	3						
	value	100	80	60						
	type	A	A	A						
	certificates	8	8	8						
player						**certificates required**		**reservation price**	**period of achievement**	
	#projects for type				**required**	#total	#buy(free)	per certificate	certificates	projects
	1	0	0	0	0	48	20(28)	17.5	-	-
	2	0	0	0	0	40	19(21)	18.75	-	-
	3	4	0	0	**4**	32	18(14)	20.65	4	7
	4	3	0	0	**3**	24	17(7)	23.75	1	3
	5	2	1	0	**3**	24	17(7)	22.92	2	4
	6	0	2	1	**3**	24	17(7)	20.42	5	7
	total	**9**	**3**	**1**	**24**	**192**	**84(84)**			

Table 4. Potential project realizations in *ACTIVITY* relevant for the bonus payment

Note: "period of achievement" denotes the period in which a player accumulates enough certificates and the respective period of the last project realization required to obtain the bonus payment. "free" refers to certificates grandfathered.

We do not expect substantial changes in overall efficiency of the system, as players striving for the bonus should mainly realize projects that would have been realized anyways. Only player 6 should realize one project worth 60 ECU lowering the total value of realized projects by 20 ECU. Note that there would still be enough certificates to achieve the bonus for either player 1 or 2, but this is precluded by the "one project per period rule". The distribution of realized projects over players should be different in comparison to *BASELINE* as the municipalities that are grandfathered the most certificates have the lowest willingness to pay for certificates within this framework. Again, for players' income, it does not matter who is going to realize the 80 ECU projects, as we assume perfect price discrimination by the state.

In sum, the *ACTIVITY* manipulation increases expected prices for certificates and leads to a redistribution of realized projects. Recall that subjects receiving the bonus represent politicians who have achieved a higher probability of reelection due to higher reputation through signaling competency and activity. However, the bonus does not add to the respective municipality's income, which only depends on the total value generated by realized projects and the net payments for certificates. As prices for certificates in the pre-election period increase, we expect a redistribution of wealth toward the state at the expense of municipalities' income, while the respective politician could be overcompensated by the bonus payment.[11]

All these considerations assume players to maximize payoffs and expect others to do so as well. Thus, all calculations described rely on the perfect ex-ante evaluation of the game by all players, which is naturally a doubtful assumption. We abstained from describing potential speculation motives, arbitrage and path dependencies. While our theoretical considerations cannot cover these outcomes in detail, they serve as a benchmark to show systematic deviations from optimal behavior and overall efficiency guaranteed by perfect foresight.

IV. Results

First, we analyze our results with respect to the efficiency of the cap & trade system in general and across treatments. Second, the dynamics of prices in auctions and markets are presented in detail. Third, we consider distributional effects between the state and municipalities and the differences between municipalities.

Welfare and Efficiency

For our analysis, we assume that the income of the state as auctioneer and the municipalities equally contribute to aggregate welfare. Recall that the state generates income exclusively by auctioning land use certificates. Municipalities pay the auction prices, which reduces their budget, and they rely on realizing projects to generate income using the certificates. Since there are no transaction costs, the only way in which this system can produce inefficiencies is through the realization of projects with lower value while projects with a higher value are still available. However, even in this case, the society's welfare deteriorates only slightly as the different project values do not deviate substantially.

Therefore, we can assess the efficiency of the system by comparing the total value from realized projects to the theoretical optimum or between treatments. Figure 2 provides these comparisons.

[11] The auctioneer can expect to sell 12 certificates at 23.75 ECU and 22.92 ECU. 20 certificates are sold to player 3; 12 at 20.65 ECU in period 4 and eight at a unit price of 20.42 ECU in period 4. Player 6 buys four certificates in period 4 at 20.42 ECU and eight at 11.25 ECU in period 5. Given the residual Type A projects, 76 certificates are further sold at 11.25 ECU and 48 at 8.75 ECU from period 11 to 15. This gives a total income of 2418.8 ECU, which is about 30% higher than in *BASELINE*.

Obviously, the cap & trade system works fairly efficiently, as there are only few deviations from the optimal allocation of certificates. Only in ACTIVITY, the average number of realized projects worth 80 ECU tends to be lower, while there are more realizations of 60 ECU projects. To look into these results in more detail, Figure 3 captures the heterogeneity among societies, as we rank societies by their net value created.

Figure 2. Realized projects by treatments

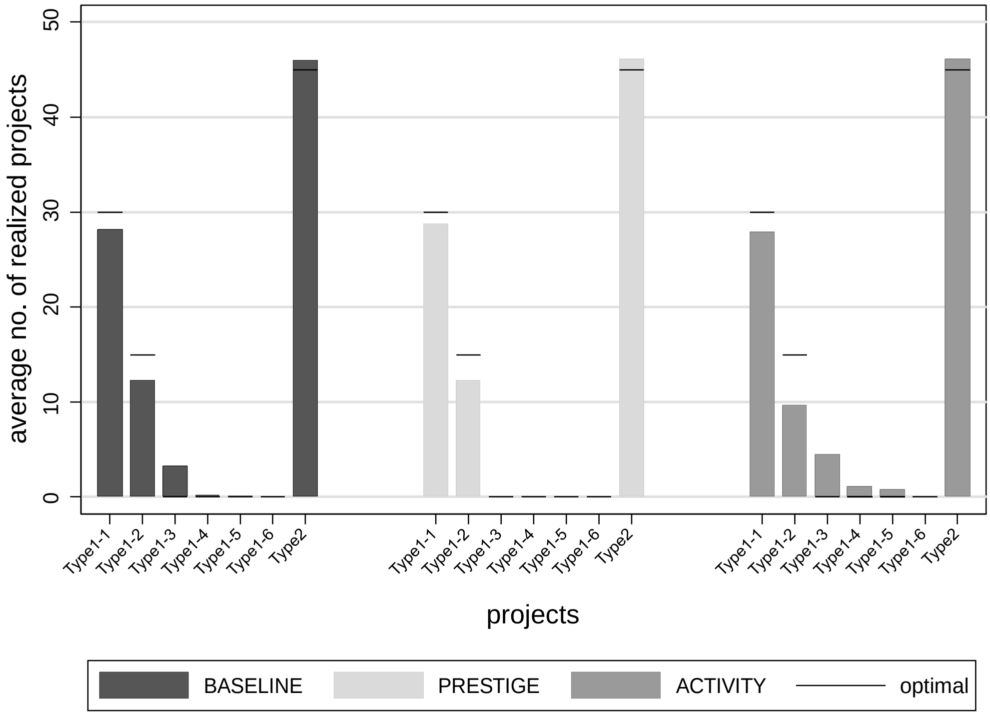
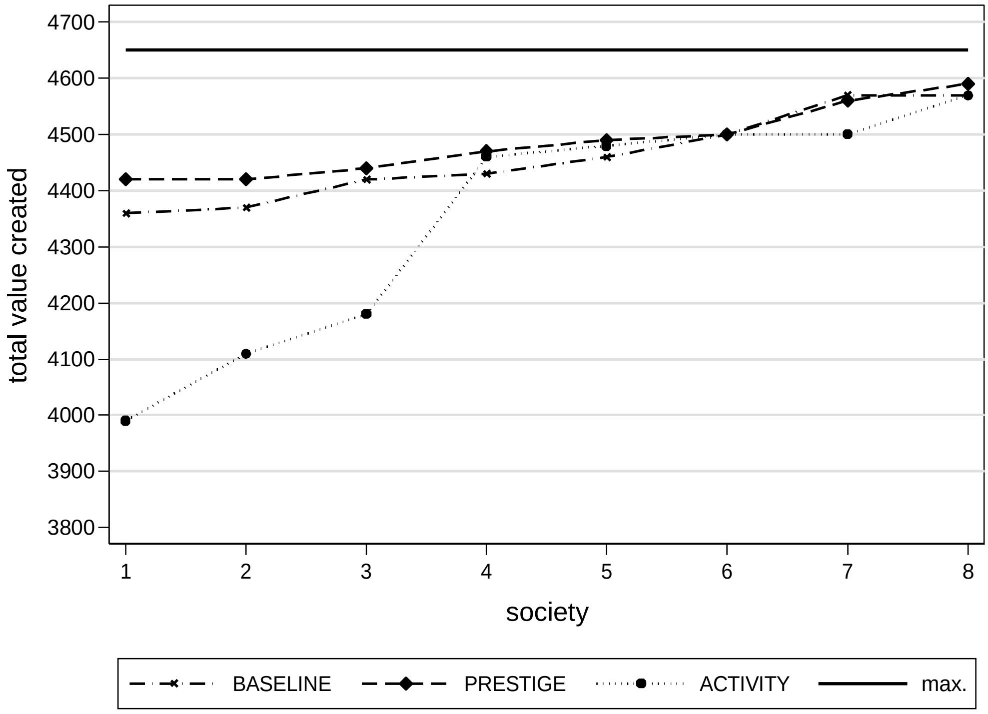


Figure 3. Realized projects by treatments



There are only minor differences between *PRESTIGE* and *BASELINE* with respect to the total value created (Wilcoxon-Rank-Sum test on the society level: z=-0.686, p=.4929). In *ACTIVITY*, three societies perform substantially worse, although, on average, there is no significant difference in comparison to *BASELINE* (Wilcoxon-Rank-Sum test on the society level: z=0.476, p=.6343). In *ACTIVITY*, the difference between the weakest and the best performance on the society level amounts to 580 ECU or about 15%, while for *BASELINE* the difference is only 210 ECU or about 5%. However, on average societies in *BASELINE/PRESTIGE/ACTIVITY* realize 96%/96.5%/93.5% of the maximum possible value.

Result 1: *The cap & trade system efficiently reduces land use. Introducing incentives for political business cycles does not substantially reduce the system's efficiency. However, in the case of strong incentives, the heterogeneity across societies tends to be higher.*

Dynamics of prices

Besides the efficiency, the dynamics of prices is of great interest when evaluating the feasibility of tradable certificates. Municipalities are quite sensitive to high price volatility since they need to make long-term plans regarding their budget and project realizations. A high volatility substantially impedes the planning and execution of profitable projects. In particular, small municipalities - which have to save certificates for several periods - may refuse to undertake such risky investments, which might result in a welfare loss as valuable projects are not realized.

Figure 4 shows the unit prices in the auction stages by treatments over periods, while Figure 5 illustrates prices in the market stage.

Figure 4. Dynamics of auction prices

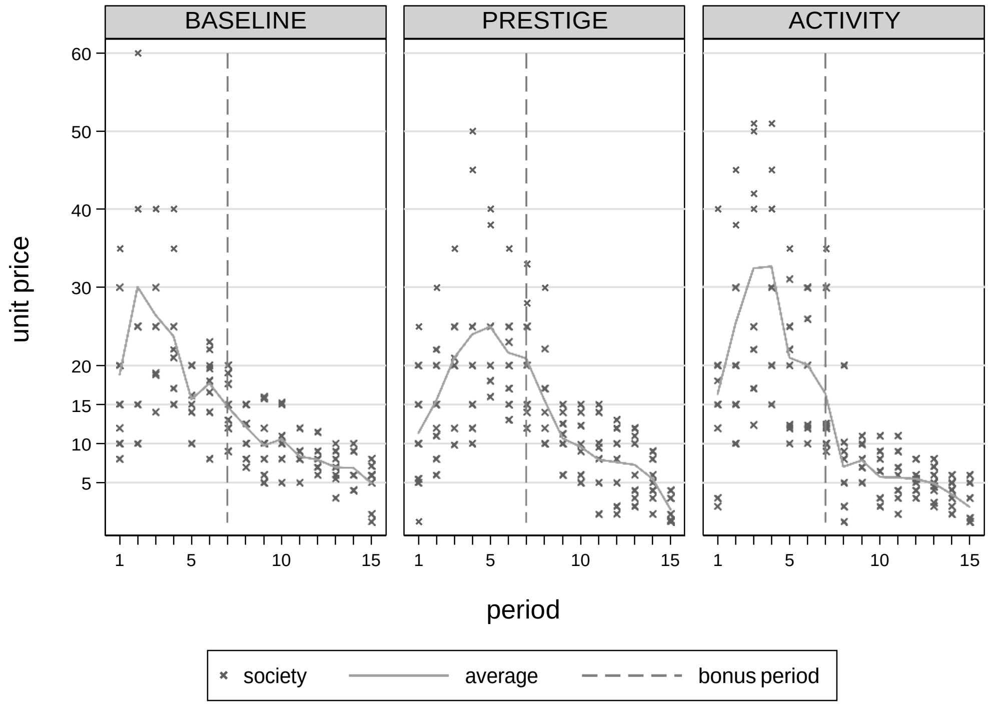
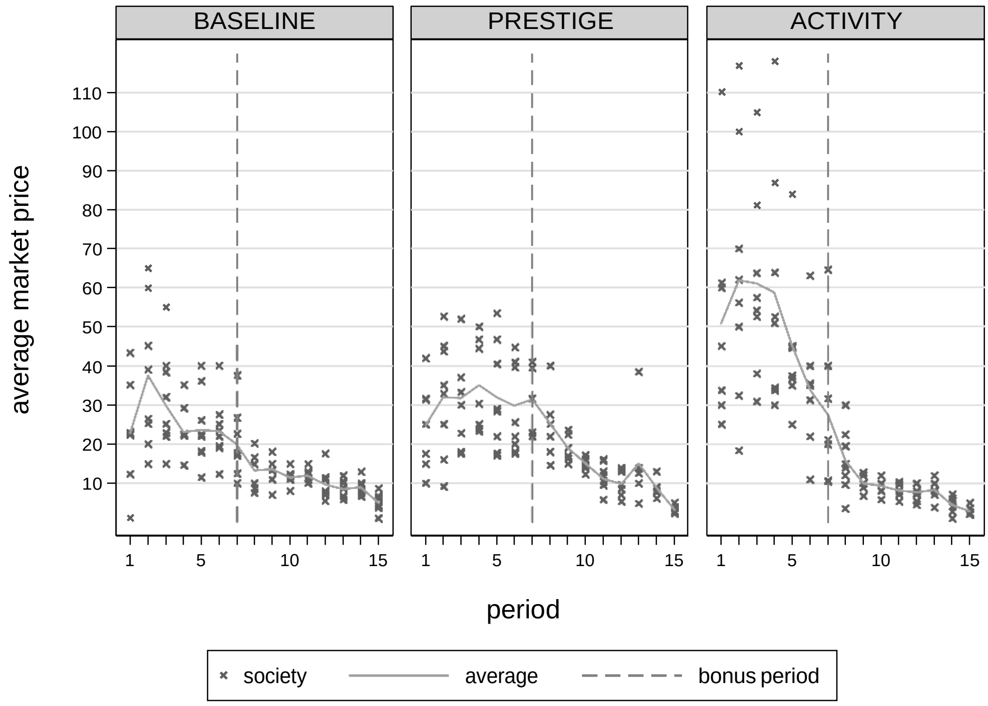


Figure 5. Dynamics of market prices



It can be seen that average prices start off fairly high for all treatments and regularly exceed the fair levels derived in section 3. Moreover, prices tend to decrease after the first couple of periods and are usually lower than the fair prices in the end of the game. This particular pattern might be due to learning effects as prices become closer to fair prices when subjects get used to the system. For all societies, the average price is strictly higher for the first half of the game when compared to the second half.[12]

Result 2: *Prices tend to substantially exceed fair values right after the introduction of the cap & trade system, before gradually deteriorating.*

The difference between the first and second half of the game is considered in detail in Table 5, which offers a compact overview of prices and reports test statistics.

		BASELINE	*PRESTIGE*	*ACTIVITY*
auction	period<=7	**20.99** (2.23)	**19.9** (6.68)	**23.43** (6.50)
	period >7	**8.43** (2.12)	**8.20** (2.78)	**5.24*** (2.39)
market	period<=7	**27.28** (7.14)	**30.45** (9.38)	**50.61***** (21.59)
	period >7	**9.70** (1.88)	**13.14**** (3.93)	**8.95** (2.67)

Table 5. Average prices and standard deviation over societies by treatment

Note: *, ** and *** indicate p-values smaller than 0.1, 0.05 and 0.01 respectively, which refer to tests against *BASELINE* applying a Wilcoxon-Rank-Sum test. Standard deviation in parentheses. All calculations are on the society level.

The gap between first and second half averages is greatest for *ACTIVITY*, which is the basic expectation following our experimental design. This pattern is even more evident and highly significant when considering market prices. The differences between *PRESTIGE* and *BASELINE* are rather small and the weak shift towards self-serving incentives has no strong influence on prices. Evidently, our treatment condition primarily influences market prices, while it hardly affects unit auction prices.

[12] Applying a Wilcoxon-Signed-Rank test for matched-pairs on the society level gives significant differences in average prices for all treatments (p<.0117).

Result 3: *Introducing strong motives for self-serving decisions inflates prices in the pre-election period, while prices substantially decrease after the elections. This effect is much stronger for market prices than for unit auction prices.*

In general, market prices exceed unit auction prices, which is especially evident in the first half of the game.[13] This gap is not in line with the hypothesis of rational agents and enables speculative earnings for subjects buying in the auction and selling in the market stage. Given this opportunity, the gap should be evened out over the course of the game. However, the difference remains strong as in *BASELINE/PRESTIGE/ACTIVITY* average prices in the market exceed unit auction prices by 15%/60%/70% in the second half of the game, which again shows that our treatment conditions primarily affect market rather than auction prices. This finding might be explained by the endowment effect (Kahneman et al., 1991), as subjects on average continue to demand higher prices for their certificates in the market place than they were willing to pay in the auction.

Result 4: *Certificate prices are substantially lower in auctions than in the markets. This systematically biased behavior can be interpreted as an endowment effect.*

Besides the development of average prices, we are interested in price volatility, which tends to increase across societies in the bonus treatments, as indicated by the lower standard deviations for *BASELINE* (see Table 5). However, the volatility within societies has to be considered and can be measured over periods (unit auction prices) or even within periods for the market stage. For unit auction prices, relying on the simple measurement of the average standard deviation, we find that in *ACTIVITY*, volatility tends to be higher in the first half of the game, i.e. in the pre-election phase. The same holds when considering market prices, while there seems to be no effect after bonus payments have been determined.[14]

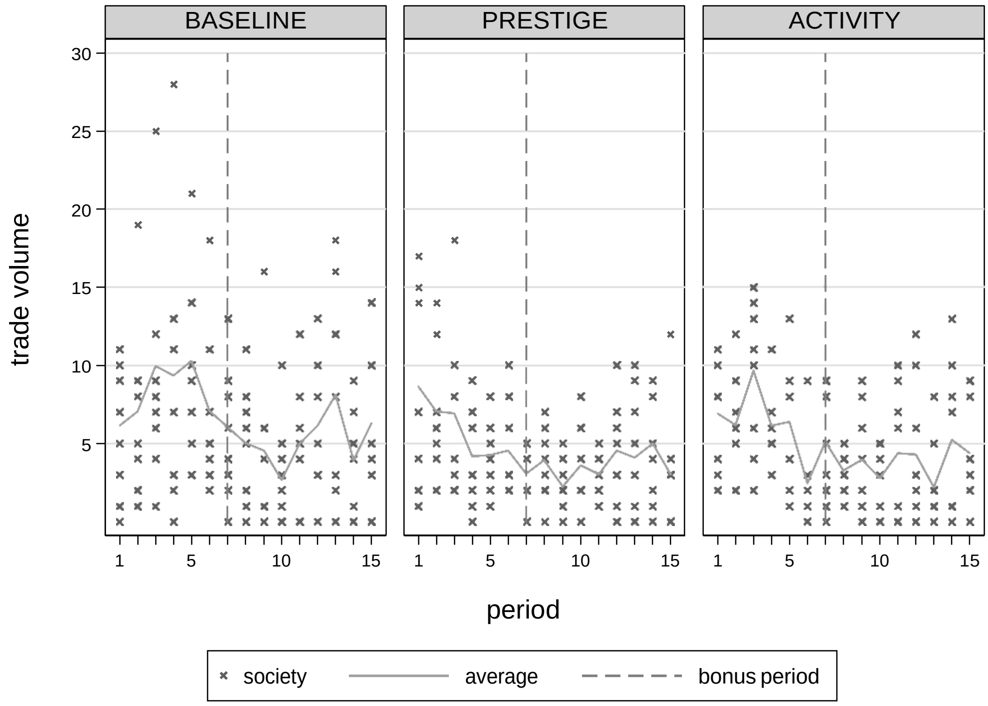
Result 5: *Price volatility in the pre-election period is increased by strong incentives for political business cycles.*

[13] For the first half of the game, applying a Wilcoxon-Signed-Rank test for matched-pairs on the society level gives z=-2.240, p=.0251 for *BASELINE*; z=-2.51, p=.0117 for *PRESTIGE* and *ACTIVITY*. For the second half, we obtain z=-1.540, p=.1235 for *BASELINE*; again z=-2.51, p=.0117 for *PRESTIGE* and *ACTIVITY*.

[14] The average standard deviation is calculated by summing the variances of auction prices of all societies within a treatment divided by the number of observation and subsequently taking the square root. For *BASELINE/ PRESTIGE/ ACTIVITY,* we get 10.68/8.25/12.0 for the first half of the game and 3.08/5.28/2.93 for the second half. Considering the average range of auction prices or the coefficient of variation gives the same tendency and ranking over treatments. We apply the same procedure for market prices, only adding the stage of standard deviations within periods, obtaining 9.15/8.77/13.03 for the first half and 2.21/7.20/1.84 for the second half.

These price differences might further affect trading volumes of certificates in the market stage; this indicator is presented in Figure 6 over periods by treatments.

Figure 6. Dynamics of market volume



For all treatments, the trading volumes tend to decrease over time.[15] We do not find significant differences in the trading volumes between *BASELINE* and *ACTIVITY* (Wilcoxon-Rank-Sum test on the society level: z=1.419, p=.1559), while in *PRESTIGE* volumes seem to be somewhat lower (z=1.682, p=.0927).

Result 6: *Trading volumes decrease over time and are not affected by self-serving incentives.*

In section 3, we derived the willingness to pay for each player and predicted that the two largest municipalities should not be able to realize the bonus payment despite their relatively high number of grandfathered certificates. However, since trading volumes do not increase due to self-serving incentives, this is a first indication that willingness to pay might not be the best predictor for the beneficiaries of the bonus payment; rather, the mere number of certificates grandfathered predominantly determines the final outcomes due to the endowment effect. To analyze this finding in detail, we consider the treatment effects on the distribution of income and project realizations between municipality players within a society.

Distributional Effects

---

[15] Wilcoxon-Signed-Rank test for matched-pairs on the society level gives z=1.823, p=.0684 for *BASELINE*; z=1.96, p=.0499 for *PRESTIGE* and z=2.38, p=.01173 for *ACTIVITY*.

The distribution of income at the state or municipality level is not relevant for an evaluation of the efficiency of a cap & trade system. However, the aspect of income distribution can be considered an important part of the political feasibility.

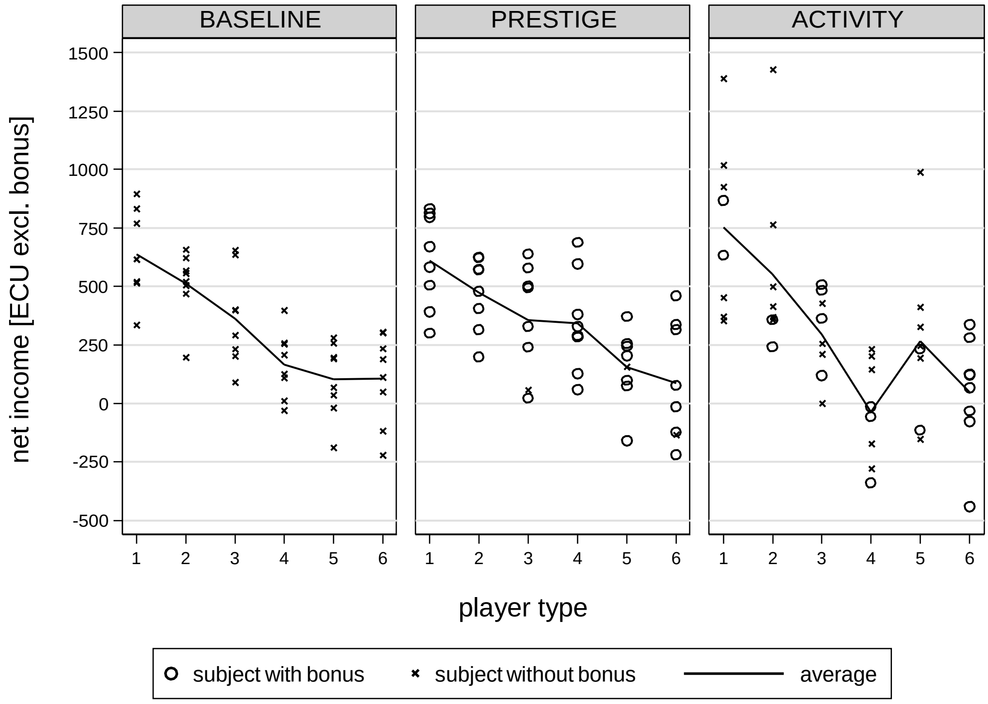
When considering the income distribution between municipalities and the state, recall that differences can only occur due to price differences in auctions, given that payments in the market stage are merely redistributing wealth among municipalities. As shown in Table 5, unit auction prices are equal across treatments. Accordingly, the distribution of income also shows no significant differences, although we expected the state's income to increase by 30% in *ACTIVITY* due to the bonus triggered higher willingness to pay. We find that in *BASELINE/PRESTIGE/ACTIVITY*, municipalities' total income (excluding bonus payment) amounts to 1887/2027/1878 ECU and state's income to 2572/2459/2470 ECU. For both municipalities' and state's income, a WRS test between respective treatment societies and in *BASELINE* gives no significant differences with all p>.34.

Result 7: *The distribution of income between the state and the municipalities does not depend on the existence of political business cycles as unit auction prices prove stable.*

Again, unlike market prices, the auction prices do not react to treatment conditions. These prices determine the distribution of wealth across municipalities. Further, in *ACTIVITY* and *PRESTIGE*, the role of the bonus payment is crucial. Politicians might try to signal activity or competency by realizing additional or prestigious projects, which might lead to losses for the respective municipalities if total expenditures for certificates exceed income yielded by this investment, while decision-makers are overcompensated by the bonus payment.

We analyze municipality players' income conditional upon size, as presented in Figure 7. Player type 1 represents the largest municipality, Player type 6 the smallest one.

Figure 7. Distribution of wealth



Since municipalities' income crucially depends on the number of grandfathered certificates and projects available, the expected pattern of wealth distribution, i.e. income decreasing along the size of the municipality, is evident for all treatments. Moreover, as expected, in *PRESTIGE* almost all players achieve the bonus payment (94%), while on average only 44% manage to do so in *ACTIVITY*. Considering treatment effects, we find no substantial differences between *BASELINE* and *PRESTIGE*. However, in *ACTIVITY*, the heterogeneity of income levels conditional on player type increases. There are more extreme values in *ACTIVITY*.

Result 8: *Municipalities' income crucially depend on certificates grandfathered and projects available. The heterogeneity of income increases with stronger incentives for political business cycles.*

Moreover, Figure 7 illustrates that the smallest municipalities (Player type 6) in *ACTIVITY* tend to realize more projects when compared to *BASELINE*, which is indicated by subjects obtaining the bonus payment. In *PRESTIGE*, almost all subjects receive the bonus, which then implies that a higher number of projects are specifically realized in period 7 compared to

BASELINE. Consequently, not only project values and allocated certificates determine the timing of project realizations but also incentives for political business cycles.[16]

Result 9: *Political business cycles influence the timing and location of land use projects realizations, i.e. the distribution over time and between small and large municipalities.*

V. Conclusion

This paper presents an experimental study to further the understanding of a cap & trade scheme as an instrument to reduce land use. Our experimental setting builds on the state of federal planning in Germany. We extend the existing literature by considering the effect of politicians seeking to enhance their reputation. Accordingly, optimal behavior from a municipality's perspective is no longer equivalent to its politician's individual maximization problem.

We find that the cap & trade system proves fairly effective in fostering the efficient reallocation of land use certificates towards the most valuable projects. However, there are major distortions aggravated in the presence of self-serving incentives. Overshooting prices in the initial periods have some municipalities bear overly high costs. High volatility in auction and market prices makes investments risky in particular for small municipalities that rely on saving certificates over many periods. Further, a strong endowment effect occurs when certificates are traded, i.e. players' willingness-to-accept in the market is systematically higher than willingness-to-pay in the auction. The heterogeneity in income and actual land use across municipalities are sensitive to the specifics of the system, as well as politicians' self-interest. Once prestigious projects play a major role in building up reputation for reelection, certificates are hoarded and land use projects are strategically postponed, which is likely to contradict real-world municipalities' interests. These distortions altogether are very likely to hinder the efficient reallocation of certificates, in particular when differences in project values and sizes of municipalities become more pronounced.

In sum, while the cap & trade system works fairly efficient, we have identified several distortions to the system. Highly volatile, biased prices, strategic hoarding, redistributional effects in income as well as the timing and location of project realizations may substantially question the political feasibility of a market-based regulatory approach. These need to be considered in particular when politicians are expected to pursue self-serving interests. Thus,

[16] Note that these results are in line with our prediction derived in the theoretical framework which shows that the smallest municipalities have the highest willingness to pay under ACTIVITY. Please find a comprehensive graphical illustration of cumulative realized projects by player type over periods in Appendix B.

despite the system's theoretical superiority in efficiently allocating land use, the distortions identified in our experimental setting might well make a traditional cap on land use the preferable regulatory choice.

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Appendix A: Instructions for the three treatments. Differences in treatments are indicated in braces; T2 refers to *PRESTIGE*, T3 refers to *ACTIVITY*.

OVERVIEW OF THE GAME

You can earn money in this game by realizing projects and trade with certificates. At the beginning, you will be randomly assigned to a group of 6 players, which will remain constant during the 15 periods of the game. All prices and values in the game will be paid in ECU with up to two positions after the decimal point. 100 ECU convert to 1€ for your payoff.

Projects

Overall, each player has 30 projects of **Type A** and 15 projects of **Type B**. Both types of projects have different values, which are shown in this table:

Type of project	Project Value (in ECU)
A	0 to 100
B	10

In each period, only one project can be realized. Before the game starts, the values of all Type A projects will be shown to you. All players are assigned different Type A projects.

Certificates

For the realization of Type A projects, you need 8 certificates each, Type B projects do not require certificates. Certificates are assigned to you at the beginning of each period and auctioned. Additionally, certificates can be traded among the players. In the game, you receive an endowment of 700 ECU, which you can use to buy certificates at the auction and from the other players. You can also sell certificates, thus increasing your payoff.

{T2&3: *Bonus payment*}

{T2: Additionally, you have the opportunity to receive a bonus payment of 300 ECU. Therefore, you will need to realize one of your most valuable projects (Type A with the highest value) in period 7. If you already realized your most valuable projects before period 7 or if you realize a less valuable project in period 7, you will not receive the bonus.}

{T3: Additionally, you have the opportunity to receive a bonus payment of 300 ECU. Therefore, you will need to realize a specific number of projects until the end of period 7. The necessary number of realized projects will be shown to you on your screen at the beginning of the game.}

Your payoff

The payoffs that you receive in the course of the game, as well as the sum of all realized projects, add up to your final payoff. Furthermore, a basic payoff of 400 ECU will be added.

COURSE OF THE GAME

Each of the 15 periods follows an identical course, which comprises three phases.

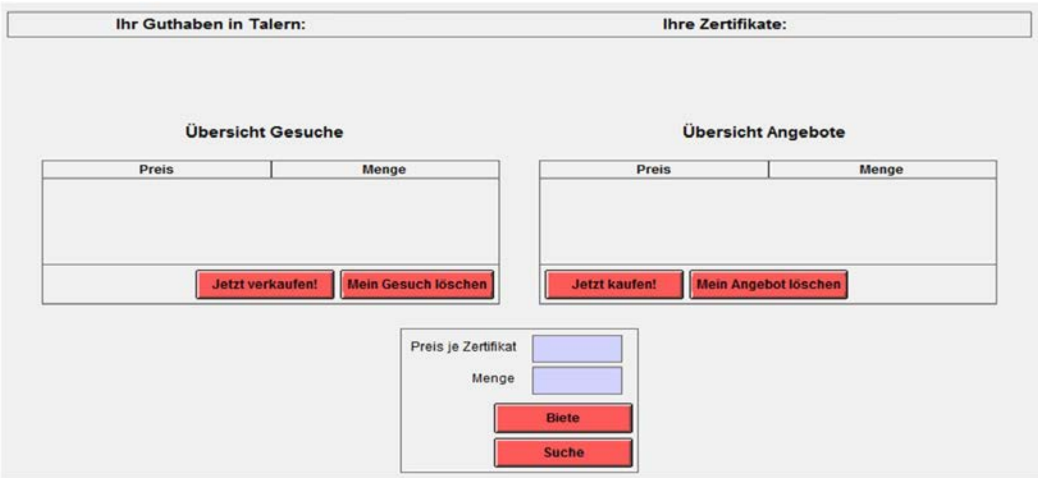
Phase 1: Issuance and auctioning of certificates

At the beginning of each period, 12 certificates are issued. The number of certificates that a player receives is determined randomly at the beginning of the game and does not change during the game.

Additionally, 12 certificates are auctioned after the issuance. Depending on your current funds, you can bid for a number of certificates of your choice at a unitary price. The 12 highest bids will receive the certificates at the price of the lowest successful bid.

Phase 2: Trading of certificates

Following the issuance and auctioning, this phase lets you trade with the other five players, i.e. buy and sell certificates. You can offer a trade yourself and accept offers from other players. To clarify this, please see the respective screen of the trading phase below:



Offering a trade

In the lower box, you can enter a price (in ECU) and the respective amount of certificates that you would like to buy.

- **By clicking "searching"**, all players are shown your buying desire in the left box. Once another player agrees to your offer, you will receive the respective number of certificates. The total value (price x quantity) of the trade will be withdrawn from your funds.
- **By clicking "offering"**, all players are shown your sell offer in the box on the right. Once another player accepts your offer, you sell the respective number of certificates. The total value (price x quantity) of the trade will be added to your funds.

Accepting another player's offer

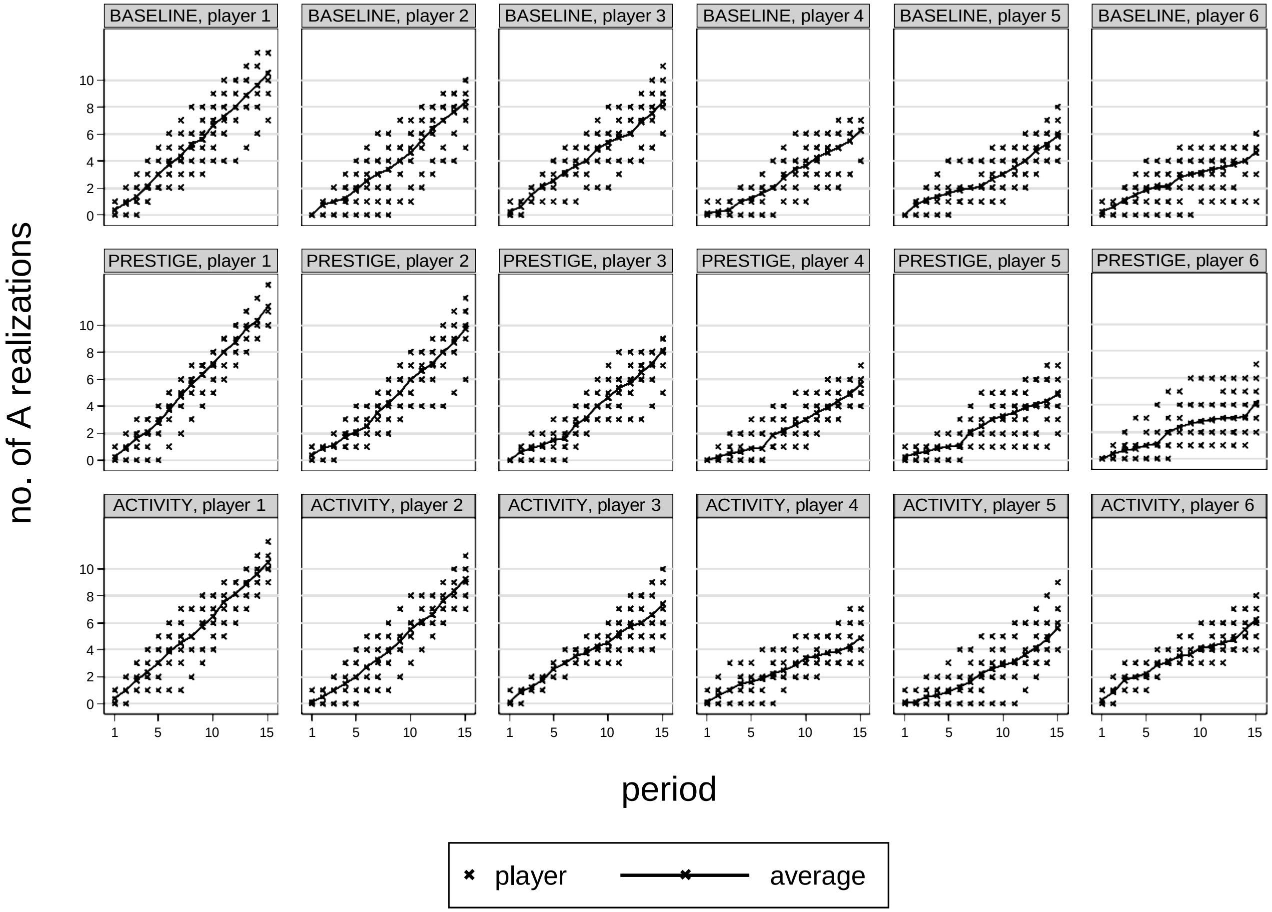
In the boxes on the right and left side, you can see all current buy and sell offers for certificates. If you choose an offer and click on "sell now!" or "buy now!", you will make the trade with the respective player.

You are allowed to trade as often as you please. You can also make multiple sell and buy offers at the same time. The trading phase ends automatically once **2 minutes** have passed.

Phase 3: Realizing projects

In the third phase of the game, you can realize one of your projects. You will receive the respective payoffs (project value in ECU) at the end of the game. After the third phase, the next period begins. Certificates that are not used in one period can be saved for subsequent periods. However, note that you will not receive a payoff for certificates that remain unused at the end of period 15!

Appendix B: Cumulative realized projects by player type over periods


BASELINE, player 1
BASELINE, player 2
BASELINE, player 3
BASELINE, player 4
BASELINE, player 5
BASELINE, player 6
PRESTIGE, player 1
PRESTIGE, player 2
PRESTIGE, player 3
PRESTIGE, player 4
PRESTIGE, player 5
PRESTIGE, player 6
ACTIVITY, player 1
ACTIVITY, player 2
ACTIVITY, player 3
ACTIVITY, player 4
ACTIVITY, player 5
ACTIVITY, player 6
no. of A realizations
period
player
average

Workingpaper Nr. 4

TRADABLE DEVELOPMENT RIGHTS UNDER UNCERTAINTY: AN EXPERIMENTAL APPROACH

von

Dr. Till Proeger, Dr. Lukas Meub und Prof. Dr. Kilian Bizer

Center for European, Governance and Economic Development Research
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Tradable development rights under uncertainty: an experimental approach

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Abstract: Tradable development rights (TDR) are discussed as a mechanism to reduce land consumption while ensuring an efficient implementation of profitable building projects. We present a novel laboratory experiment on the feasibility of TDR and simulate the acquisition and trading of development rights. In particular, we investigate the effects of uncertainty in the revenues of land consumption projects. Overall, we find that TDR are reallocated as suggested by theory, although higher uncertainty has substantial detrimental effects on the distribution of land consumption projects and thus aggregate welfare. This enables us to formulate distinct policy implications for the design of TDR systems.

Keywords: auction, economic experiment, land consumption, tradable planning permits, urban sprawl

JEL Classification: C91; C92; D8

1. Introduction

Tradable development rights (TDR) are discussed as a policy instrument to reduce urban sprawl and foster a more sustainable land use. Such market-oriented planning instruments are increasingly considered in scientific and political discourses as a viable extension of urban containment strategies (van der Veen et al., 2010), suggesting that they show superior efficiency in achieving reductions of land consumption (Miller, 1999; Nuissl and Schroeter-Schlaack, 2009). Implementing a quantitative constraint - i.e. a cap - on development rights along with a trading mechanism and floating prices would constitute a system enabling policy-makers to accomplish reductions in land use with near-perfect precision at minimal cost. Furthermore, planners and land-owners are expected to use land more efficiently in a system of TDR, fostering inner-city development and gaining a greater awareness of the ecological problems that stem from excessive urban sprawl (Levinson, 1997; Henger and Bizer, 2010).

The United States was the first nation to implement TDR on a large scale in more than 30 federal states from the 1970s onwards, within very different regional and institutional contexts (Pruetz, 1997). The heterogeneity of the programs in question makes overarching evaluations of their efficacy challenging. While several studies have provided initial empirical results on universal success factors for TDR (e.g. Kaplowitz et al., 2008; Pruetz and Standridge, 2009; Tan and Beckman, 2010; Chan and Hou, 2015), the empirical evidence that can be utilized for providing generalizable policy advice remains limited (Bengston et al., 2004; Kopits et al., 2008). This is problematic as TDR are increasingly considered as a means of establishing sustainable land use policies in numerous developed nations, including the Netherlands (Janessen-Jansen, 2008), Italy (Micelli, 2003), Australia (Harman and Choy, 2011), Switzerland (Mengini et al., 2015), China (Wang et al., 2009) and Germany (Henger and

Bizer, 2010), where the current administration has decided to develop and test a nation-wide system of TDR (Coalition Treaty, 2013).

In this paper, we argue that empirical evidence derived from economic laboratory studies can be considered a worthwhile addition to the existing purely theoretical analyses, local case studies and supra-regional surveys. Laboratory experiments can answer specific counterfactual research questions that remain inaccessible for theoretical and empirical studies relying on field data (Greenstone and Gayer, 2009; Falk and Heckman, 2009; Chetty, 2015). Therefore, we propose a research design that enables us to simulate a system of TDR and measure agents' reactions to changes in core institutional parameters. This is achieved through a novel experimental design that simulates the allocation and trading of development rights as well as the ensuing realization of building projects using the development rights acquired beforehand in the game. Our setting implements a fairly general concept of a TDR system applicable to different institutional and national contexts. In addition to providing evidence on the overall efficiency and welfare implications of a TDR system, we investigate a key feature of land consumption projects, namely the investment risk associated with acquiring, trading and using development rights. This research question builds upon a broad strand of literature in experimental economics showing that individual decision-making under risk leads to substantially different outcomes than those predicted by benchmarks of rational decision-making (see e.g. Camerer et al., 2011). Consequently, we ask how subjects and the overall system react when the revenues of land consumption projects are prone to uncertainty and potentially yield negative returns compared to a situation with fixed, positive returns. This enables us to show whether markets cease to allocate development rights efficiently when faced with uncertainty in future revenues as a crucial property of investments in TDR and thus fail to maximize welfare. Consequently, the overall viability of a TDR market may depend on a specific sector's volatility in revenues.

The subsequent section of this paper justifies our methodological choice and reviews the relevant literature, while our experimental design and benchmark model are outlined in sections three and four, respectively. The experimental results are presented in section five, before section six discusses our results and provides a conclusion.

2. TDR and laboratory experiments

Evaluating the policy options of implementing TDR on a large scale is associated with the lack of generalizable empirical evidence presented to justify the choice of specific institutional mechanisms. While a number of theoretical publications have laid out the potential advantages of TDR (for a basic setup, see Thorsnes and Simons, 1999; recent theoretical contributions are provided by Ward, 2013; Vejchodska, 2015), few specific institutional implications can be derived from these studies due to their level of abstraction and the ubiquitous assumption of rational agents that forms the basis for the optimistic predictions about the efficiency of TDR. At the same time, a similarly large body of overview studies for heterogeneous institutional and social contexts has been presented, providing determinants of successful implementations of TDR (for studies based on qualitative measures, see e.g. Santos et al., 2015; Harman et al., 2015; Kaplowitz et al., 2008; Machemer and Kaplowitz, 2002; Pruetz and Standridge, 1999; Danner, 1997; studies primarily using quantitative measures include Menghini et al., 2015; Kopits et al., 2008; Lynch and Musser, 2001; Lynch and Lovell, 2003). While an overall consensus has been established in the literature concerning a number of success factors of TDR systems (such as strong demand for additional development zones and receiving areas customized to the demands of the respective communities (Pruetz and Standridge, 2009)), we argue that these conclusions remain closely tied to specific regional and institutional contexts. Accordingly, they are not fully generalizable and often inapplicable to other nations’ implementation of TDR.

We suggest that laboratory experiments can provide additional insights into the policy-oriented discussion of TDR and fruitfully complement the existing literature. Laboratory experiments can effectively provide a link between theoretical studies with a perfect internal validity yet disputable external validity in a world of non-rational agents and case studies with a perfect external validity yet a lower generalizability. Proponents of laboratory studies in policy-related discussions argue that experimental evidence combines a high internal validity (ensured by controlling all environmental factors) with a high external validity by testing actual human behavioral patterns in situations that resemble certain institutions relevant for policy-makers (see e.g. Charness and Fehr, 2015 and Santos, 2011 for comprehensive discussions as well as Greenstone and Gayer, 2009 with a focus on environmental policy).[1] A successful example of this approach - i.e. using laboratory experiments to provide policy-makers with information on the effects of different potential institutional choices – can be found conducted in the run-up to the 2005 implementation of tradable CO_2 certificates within the European emissions trading system (ETS). A long-standing scientific discussion was established that built upon theoretical modeling of the trading system and subsequently provided experimental evidence from which distinct policy implications could be deducted (see Convery, 2009 as well as Grimm and Illieva, 2013 for comprehensive overviews of the discussion as well as Stranlund et al., 2014 for a recent experimental contribution). Another recent example is the experimental investigation of water quality trading markets, furthered e.g. by Jones and Vossler (2014).

Our paper aims to contribute similarly to the study of the optimal design of TDR. We present empirical evidence on the validity of theoretical assumptions concerning individual behavior

[1] The debate on the merits and potential disadvantages of applying behavioral economics to the design of public policies has been conducted for more than a decade by now. Among the central contributions are Falk and Fehr (2003), Falk and Heckman (2009), Madrian (2014) and Chetty (2015), who present the core arguments.

within a TDR system and deduct more general behavioral patterns applicable to policy-making. We can build upon a small number of previous papers that have tested specific aspects of a system of TDR. For instance, Henger (2013) compares the performance of student participants and municipal planners, finding that both groups achieve a fairly efficient allocation of certificates. Moreover, Meub et al. (2017) consider the influence of political business cycles within a TDR system, while Meub et al. (2017) investigate the efficiency of different mechanisms for allocating development rights, Meub et al. (2016) show the impact of macroeconomic shocks on a system of TDR and Proeger et al. (2016) experimentally consider the influence of communication regimes on the efficiency of TDR schemes.

The experiment reported in this paper extends the previous studies by providing evidence on individual decision-making under risk and its consequences for the overall efficiency within a TDR system. Decision-making under uncertainty has been among the primary subjects for experimental economists examining the validity of neoclassical assumptions on rational behavior. It has become a standard assumption that subjects' behavior can substantially deviate from benchmark models of rational decision-making assuming risk-neutral behavior in numerous economic and institutional contexts (see e.g. Camerer et al., 2011 and Cox and Harrison, 2008 for introductions to the literature; see Charness et al., 2013 and Crosetto and Filippin, 2013 for the state of research on risk preferences). These more realistic insights about dealing with risk necessarily imply very different policy recommendations than those derived from theoretical models merely assuming risk-neutral agents. Therefore, it remains an open question whether and how agents in an actual TDR system will successfully cope with the uncertainties associated with investing resources in development rights to conduct building projects. Risk preferences might substantially influence the distribution of TDR, auction and market prices and consequently overall efficiency. Our experimental design can shed light upon this question by investigating subjects' reactions to uncertainty in future revenues while implementing the core features of a TDR system.

3. Experimental design

3.1 Implementation of TDR in an experimental framework

Our experimental design aims to implement a fairly general concept of TDRs, enabling the transfer of insights to different national or institutional contexts. Our basic approach resembles the cap & trade system for CO_2 emissions, whereby certificates are issued by a public authority and used by different agents for their production. Whenever the expected income from a production does not compensate the costs of the number of certificates required, the production will not be undertaken. Overall, given a redistribution of issued certificates through a trading system, only the most profitable units of productions are realized.

This approach is transferred to land consumption, whereby we assume that agents aim to realize building projects that yield revenue in the future. These agents could potentially be municipalities, firms or individual residents. There is an authority – most likely a public institution or large private landowner – who sets a cap on overall land consumption and allocates certificates (i.e. development rights) in accordance with the cap. Similar to CO_2 markets, certificates are issued in two distinct ways: a certain amount is allocated for free ("grandfathered") by a predetermined allocation formula and the remaining certificates are auctioned. Hence, all agents receive a number of TDR by default and bid on additional ones, both of which they can subsequently use to realize their building projects or – if more profitable – sell to other agents. Accordingly, "sending sites" and "receiving sites" are determined in a market process, optimally by redistributing TDR to the most profitable sites. We further assume heterogeneous agents within a market, which simulates different sizes of the public institutions or landowners and translates to a different number of projects available and certificates grandfathered to the respective agents.

Besides providing evidence on the working mechanism of a laboratory-based TDR-scheme, we investigate the element of risk in the context of acquiring and using certificates for land consumption. We argue that the uncertain outcome of investing and conducting building projects within a system of TDR could substantially alter its feasibility and distort the efficient allocation of certificates. This basic feature of land use decisions is implemented by assigning different degrees of profitability to each project, which are equally likely to realize at the end of the game. We thus assert how participants react to varying degrees of profitability as one representation of underlying risk.

3.2 Overview of the game

Note that the general experimental design uses the framework introduced by Meub et al. (2016). In the game, groups ("markets") of six participants are matched to interact for 15 periods. These subjects generate payoffs by realizing projects and trading certificates. There are two types of projects available. First, there are Type A projects, which generate between 0- and 100ECU, whereby 100ECU converts to 1€ at the end of the game. These projects require eight certificates to be realized and thus represent land consuming building projects. Independent of their distinct value, all Type A projects require the same number of certificates, whereby this simplification is intended to keep the game comprehensible for the participants. Second, an outside option is given by Type B projects that always pay 10ECU.

Prior to the first period, subjects are randomly assigned to a specific player type determining their endowment of available projects and certificates. Independent of the player type, all subjects are initially endowed with a budget of 700ECU. Each period of the game comprises three stages.

Within the first stage, subjects accumulate certificates that are required to conduct Type A projects. Half of the 24 certificates issued in each period are grandfathered, whereas the other half are auctioned in a uniform price auction with sealed bids. Accordingly, subjects' bids for certain quantities are ranked by price and the lowest bid that is granted certificates determines the uniform price.

A double auction market constitutes the second stage of each period, during which subjects can simultaneously buy and sell certificates within their budget constraint, i.e. there is no borrowing to buy certificates. The secondary market is open for two minutes and there are no transaction costs. This setting enables subjects to gamble and try to generate income by taking advantage of price dynamics and thus expand or reduce their budget and stock of certificates.

At the end of each period, subjects have to choose between using certificates to realize a project of Type A or relying on the outside option of realizing a Type B project, meaning that they had to choose Type B if they chose not to conduct a Type A project. Only one project can be realized per period. While participants can conduct projects in each period, their payoff is not granted until the final period. This design choice implements a core feature of building projects – namely their duration and the delay until investments pay off – and again provides funds that can be invested anew. Certificates can be kept across periods, i.e. our design allows for banking of certificates. However, all remaining certificates lose their value after the final period. Subjects receive feedback on their decisions after each period.

Table 1 summarizes the properties of the game by listing all player types with their available projects and certificates.

project	type	A-1	A-2	A-3	A-4	A-5	A-6	B			
	value	100	80	60	40	20	0	10			
	certificates	8	8	8	8	8	8	0			
									total	**certificates period (total)**	
										#grandfathered	#auctioned
agent	**1**	10	8	6	4	2	0	15	**45**	4(60)	-
	2	8	10	6	4	2	0	15	**45**	3(45)	-
	3	6	8	10	4	2	0	15	**45**	2(30)	-
	4	4	6	8	10	2	0	15	**45**	1(15)	-
	5	2	4	6	8	10	0	15	**45**	1(15)	-
	6	0	2	4	6	8	10	15	**45**	1(15)	-
	total	**30**	**38**	**40**	**36**	**26**	**10**	**90**	**270**	**12(180)**	**12(180)**

Table 1. Overview of the different player and project types as well as the respective certificates.

Note: The table first provides details on the different projects, whereby six Type A projects with different values are available, each requiring eight certificates. The Type B project is the outside option in each period and thus does not require certificates. Furthermore, the table shows details on the different player types (on the lower left half): there are six player types, endowed with varying numbers of projects. Overall, each player type has 45 projects available. The lower right hand side shows the number of certificates provided to the respective player type in each period and - in brackets - during the entire game.

3.3 Treatment conditions

Our treatments introduce risk in project revenues as a key feature of all investment projects, which similarly translates to land consumption projects that typically take some time before revenues are realized. Risk has to be considered to hold outstanding importance as it potentially distorts the efficient allocation of certificates in a cap & trade system.

The two treatments *LOW RISK* and *HIGH RISK* differ in terms of the associated risk in project revenues, which is summarized in table 2. The three degrees of profitability for each period are equally likely to realize, i.e. with a probability of 1/3.

Project	***BASELINE***			***LOW RISK***			***HIGH RISK***		
	low	medium	high	low	medium	high	low	medium	high
A-1	-	100	-	50	100	150	-100	100	300
A-2	-	80	-	40	80	120	-80	80	240
A-3	-	60	-	30	60	90	-60	60	180
A-4	-	40	-	20	40	60	-40	40	120
A-5	-	20	-	10	20	30	-20	20	60
A-6	-	0	-	0	0	0	0	0	0
B	-	10	-	10	10	10	10	10	10

Table 2. Overview of project values with respect to treatment conditions.

Note: The table provides the different projects (A1-6, B) and the different potential outcomes conditional on treatments. Each of the three potential outcomes (low, medium, high) is equally likely to be realized. Consequently, the expected profitability is equal in all three treatments.

Participants are provided with this distribution of potential project payoffs in the instructions of the respective treatment. Furthermore, the distribution in payoffs is displayed to the participants before each auction when an overview of available projects is provided and in the third stage of each period when subjects make their choice whether or not to realize projects. While subjects are aware of the risk associated with conducting Type A projects, they are shown which of the three degrees of profitability has realized after the final period, along with their payoff for the projects. We thus avoid potential path dependencies in a group's decision triggered by particularly good or bad outcomes within the first periods of the game.

3.4 Experimental procedure

Table 3 provides an overview of our treatments as well as the respective number of participants. Note that the benchmark treatment (*BASELINE*) is also used in Meub et al. (2016).

Treatment	Risk condition	No. of participants	No. of societies
BASELINE	no	48	8
LOW RISK	low	54	9
HIGH RISK	high	48	8
Total		**150**	**25**

Table 3. Overview of the different treatments and the number of participants.

The experiments were conducted in the Laboratory for Behavioral Economics at the University of Goettingen using z-Tree (Fischbacher, 2007) and ORSEE (Greiner, 2004). There were 5 sessions in November 2015, whereby subjects were only allowed to participate in one session. We ensured a common understanding of the game prior to each experimental session by having subjects answer mandatory control questions. The original instructions for the game were in German can be obtained from the authors upon request; an English translation is provided in the appendix. The sessions had an average duration of 80 minutes and the average individual payment amounted to 14.3€, including a show up-fee of 4€. Subjects were students of different academic disciplines (with 38.5% students of economics and business administration), they were on average 24.8 years old and 56.9% were female.

4. Theoretical framework and expected results

General properties of the game: BASELINE

Our basic setup implements a cap & trade system to achieve the regulatory goal of restricting land consumption. Considering a situation without a cap, table 1 emphasizes that each agent would conduct one Type A project in each of the 15 periods, which gives a total of 90 Type A projects for a society of six players throughout the game. However, the implemented cap only allows for half of these projects to be realized given that only 24 tradable planning permits are issued in each period and eight of them are required to conduct one Type A project. Hence, the cap reduces the number of land consuming Type A projects from 90 to 45. Thereby, an agent's willingness to pay (WTP) – as derived by her endowment of projects – determines whether or not she carries out projects in the equilibrium, assuming optimal behavior and an efficient reallocation of certificates.

An agent's maximal achievable income by using eight certificates is 100ECU for conducting a Type A-1 project with an outside option of 10ECU for conducting a Type B project. Accordingly, the WTP for one certificate is calculated by (100ECU – 10ECU)/8= 11.25ECU. While prices should not exceed this value they might well be lower, given that there are only 30 Type A-1 projects and thus there should be 15 Type A-2 projects carried out with an agent's WTP at (80ECU-10ECU)/8= 8.75ECU. However, agents are not aware of this distribution of projects, which leads to the expectation of certificate prices being within the range between 8.75ECU and 11.25ECU. At these fair prices, certificates should be optimally redistributed such that 30 Type A-1 and 15 Type A-2 projects are carried out and – due to the implemented cap – 45 Type B projects.

The auctioning of certificates transfers income from agents to the auctioneer in accordance with agents' WTP. The income of the auctioneer is a share of the total wealth generated by realized projects and is irrelevant when assessing the overall efficiency of the system. However, the political feasibility of a regulatory cap & trade system might crucially depend on a distribution of wealth between the auctioneer and the involved agents considered to be fair by its participants. As mentioned above, prices as unit auction prices should reflect agents' WTP. Overall, 180 certificates (12 in each of the 15 periods) are auctioned, whereby – based upon the distribution of Type A projects – we could assume two-thirds of the certificates being sold at a unit prices that equal the maximal WTP of 11.25ECU and one-third being sold at the lower bound of fair prices given by 8.75ECU.

Table 4 summarizes these theoretical considerations and predictions for an efficient cap & trade system.

project	**type**	A-1	A-2	B	
	value	100	80	10	
	certificates	8	8	0	
					total
land consumption	**# realizations**	30	15	45	**90**
wealth	**total value**	3000	1200	450	**4650**
certificates	**# bought**	120	60	0	**180**
	# free	120	60	0	**180**
income	**agents**	1650	675	450	**2775**
	auctioneer	1350	525	0	**1875**

Table 4. Theoretical predictions in equilibrium.

Behavior under the treatment condition of risk

Our two treatment conditions introduce risk to the general setting of the game. If we assume that agents are risk neutral, all theoretical predictions remain valid. Risk-neutral agents act according to expected payoffs of projects and thus the WTP and the expected income distribution derived above remains unchanged.

However, agents might well have risk-loving or risk-averse preferences, whereby an agent's WTP might be driven by her risk preferences rather than solely by available projects. For risk-loving agents, ceteris paribus, the WTP is higher in the risk treatments as there is the possibility to generate more income from the same projects. By contrast, for risk-averse agents, the WTP is lower following the reverse argument. In *HIGH RISK*, the differences in WTP should be higher than in *LOW RISK* as the spread in potential income from one project is higher and income might even become negative. Similarly, the auctioneer's income crucially depends on the distribution of risk preferences and it might be higher or lower compared to the expected 1875 ECU in *BASELINE*.

Considering overall welfare as measured by total value generated by realized projects, risk preferences are irrelevant if agents are homogenous. Furthermore, risk preferences are not harmful if those agents endowed with the most valuable projects are also the most risk-loving. In this case, the adjustments in WTP according to risk preferences would coincide with the ranking of agents according to their available projects. Put simply, if risk preferences are distributed such that projects continue to be conducted as determined by the WTP in the absence of risk, the cap & trade system upholds its theoretical efficiency. However, it appears unlikely that land consumption projects are always distributed according to agents' risk preferences; rather, it is more likely that agents characterized by their risk preferences are randomly distributed across potential project endowments, which is simulated in our experiment. Therefore, we expect realized projects to be distributed differently in the risk treatments, i.e. being influenced by the distribution of risk preferences and thus distorting the overall efficiency.

To illustrate these expected changes due to the treatment conditions, consider the simplified case of two agents in *LOW RISK* or *HIGH RISK*: agent *cautious* has a Type A-1 project with an expected payoff of 100ECU and agent *gambler* has a Type A-2 project with an expected payoff of 80ECU.

Without risk, agent *cautious* would bid 11.25ECU per certificate in an auction, leaving her with a minimum profit of 10ECU when granted the certificates, which is equal to the outside option. Under risk, her WTP might be considerably lower as the expected payoff of 10ECU is less favorable than the 10ECU certain profit of the outside option; accordingly, her WTP becomes (11.25ECU – *risk premium*^{cautious}).

Agent *gambler* would bid 8.75ECU per certificate in the absence of risk, again leaving her with a certain profit equal to the outside option of 10ECU. However, as *gambler* favors risk, she is willing to pay more per certificate if there is an upside outcome of more than the 80ECU, even if it is mirrored by a symmetric downside outcome; accordingly, her WTP becomes (8.75ECU + *risk premium*^{gambler}). Consequently, the efficiency of the certificate allocation only holds if (11.25ECU – *risk premium*^{cautious}) > (8.75ECU + *risk premium*^{gambler}). If this condition is violated, the less valuable project is realized and a loss in expected aggregate income of 20ECU results.

As the expected aggregate income of all participants is the main policy objective, a cap & trade system might lose the core advantage assumed by its proponents, i.e. efficiency in the allocation of certificates. Our experiment investigates these potential distortions and allows us to identify additional effects and problems associated with risk in land consumption project revenues.

Despite heterogeneous risk preferences, our theoretical framework only considers homogenous agents, i.e. endowed with identical cognitive abilities, as well as perfect foresight and understanding of the game. This precludes speculation motives and path dependencies in auction or market prices as subjects are fully capable of a perfect ex-ante analysis and rational decision-making. Although these assumptions are highly unlikely to be met by experimental participants, the predictions deducted above serve as useful benchmarks in evaluating the observed behavior and identifying typical behavioral patterns that might explain distortions to the system's efficiency.

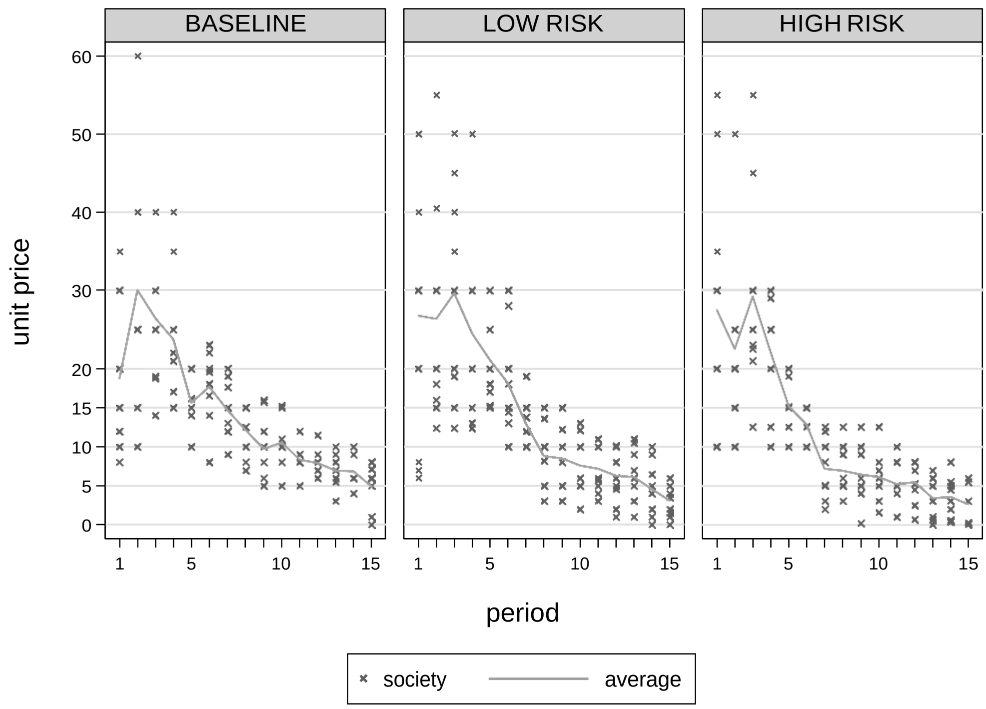
5. Results

We present our results in the order of the game's three stages and according to the treatment conditions: first, we investigate auction prices and distributional effects between agents and the auctioneer; second, price dynamics and trade volumes in the secondary market are analyzed; and third, we illustrate which projects are carried out and which land consumption results. To provide an overarching conclusion, we assess the overall efficiency of the cap & trade system and evaluate differences in income with respect to agent types.

5.1 Auctioning of certificates

In each period, half of the issued certificates are auctioned in a uniform price auction. As shown in our theoretical analysis (section 4), prices should not exceed the fair value of 11.25ECU, assuming agents are risk neutral. Figure 1 illustrates auction prices over periods with respect to treatment conditions.

Figure 1. Price dynamics in auctions by treatments



It can be seen that price dynamics across periods are fairly similar. Prices significantly exceed the fair value at the beginning, before gradually decreasing to a level further below the fair value. The decrease in prices initially appears to be rather steep yet it becomes weaker from about period 7 onwards. Table 5 summarizes the unit auction prices at the society level and provides statistical evidence.

		BASELINE	*LOW RISK*	*HIGH RISK*
unit prices	period<=7	**20.99**	**22.78**	**19.5**
		(2.23)	(8.11)	(5.01)
	period >7	**8.43**	**6.54**	**5.00****
		(2.12)	(3.18)	(3.18)
	overall	**14.29**	**14.12**	**11.77****
		(1.55)	(2.70)	(1.71)

Table 5. Averages and standard deviations of unit auction prices by treatment

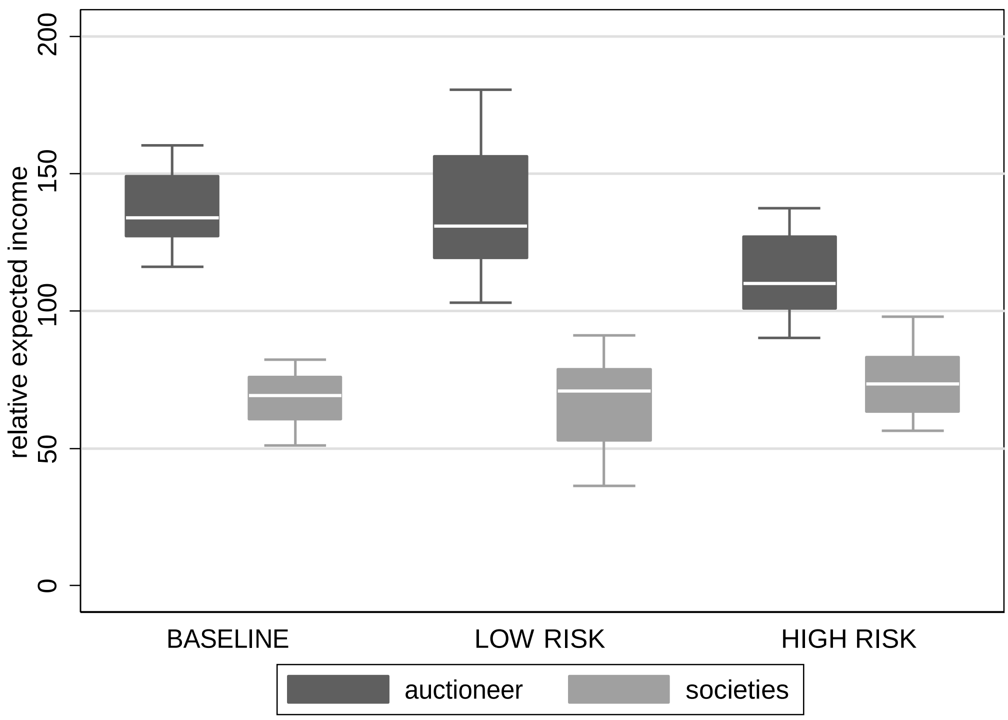
Note: Applying a Wilcoxon-Rank-Sum test against *BASELINE where* *, ** and *** indicate p-values smaller than 0.1, 0.05 and 0.01, respectively; standard deviations in parentheses. Unless mentioned otherwise, all calculations and tests are carried out at the society level.

For all treatments, prices are substantially lower in the second half of the game (Wilcoxon-Sign-Rank test; for *BASELINE* z=2.521 and p=.0117, for *LOW RISK* z=2.666 and p=.0077, for *HIGH RISK* z=2.521 and p=.0117). On average, prices in *HIGH RISK* are closest to our theoretical predictions and, more interestingly, they are significantly lower than in *BASELINE* and *LOW RISK*.

Result 1a: *Independent of the underlying risk in project revenues, unit auction prices initially exceed fair values, yet tend to gradually decrease in a TDR system. High underlying risk reduces auction prices.*

Recall that all payments in auctions transfer to income for the public authority auctioning the certificates. Figure 2 depicts the auctioneer's and societies' total expected income relative to the theoretical values derived above. A society's total expected income is derived by aggregating the expected values of realized projects and subtracting aggregate payments in the auctions.

Figure 2. Distribution of income between auctioneer and societies by treatment



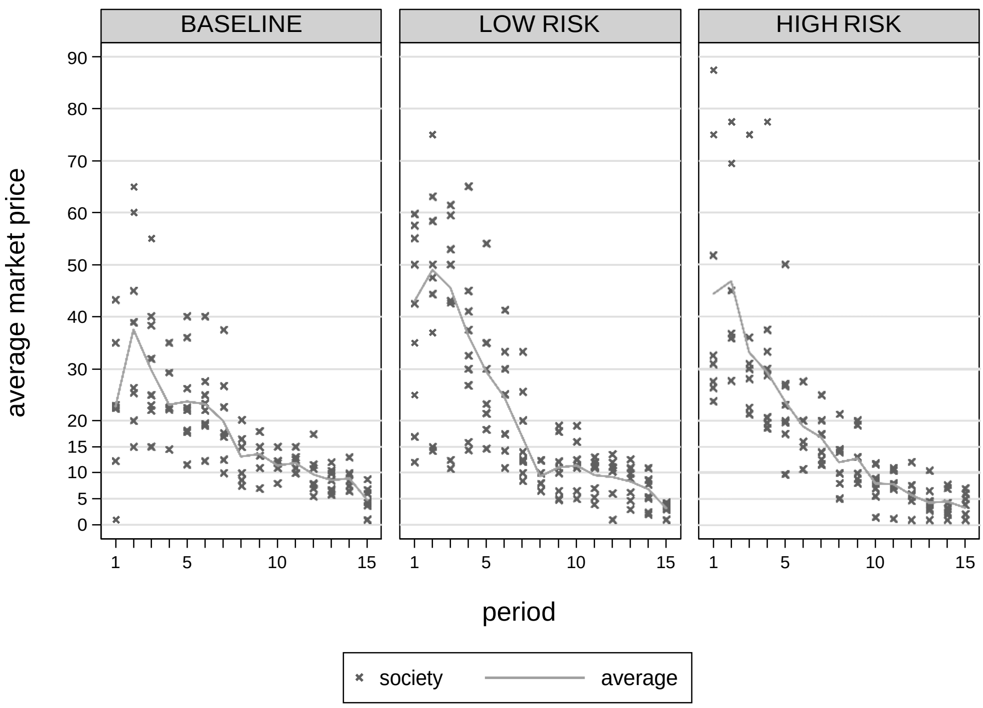
It can be seen that the auctioneer outperforms the theoretical benchmark, while societies perform worse. This finding corresponds to Figure 1 and provides evidence of fairly high prices in the initial periods, which benefit the auctioneer to a greater extent than the lower prices during later periods diminish her income. Another interesting result from this illustration is the substantially lower income discrepancy in *HIGH RISK* compared to *BASELINE* or *LOW RISK*. It appears that agents confronted with a high level of uncertainty become more cautious throughout the game when bidding in the auction to accumulate certificates, which in turn substantially reduces the auctioneer's income. Overall, these findings can be explained by the prevalence of risk-averse behavior among agents.

Result 1b: *Auctions in a TDR system redistribute income from agents to the auctioneer to a much greater extent than suggested by theory. This effect is weaker when the underlying risk is high as agents bid less and show risk-averse behavior.*

5.2 Trading of certificates

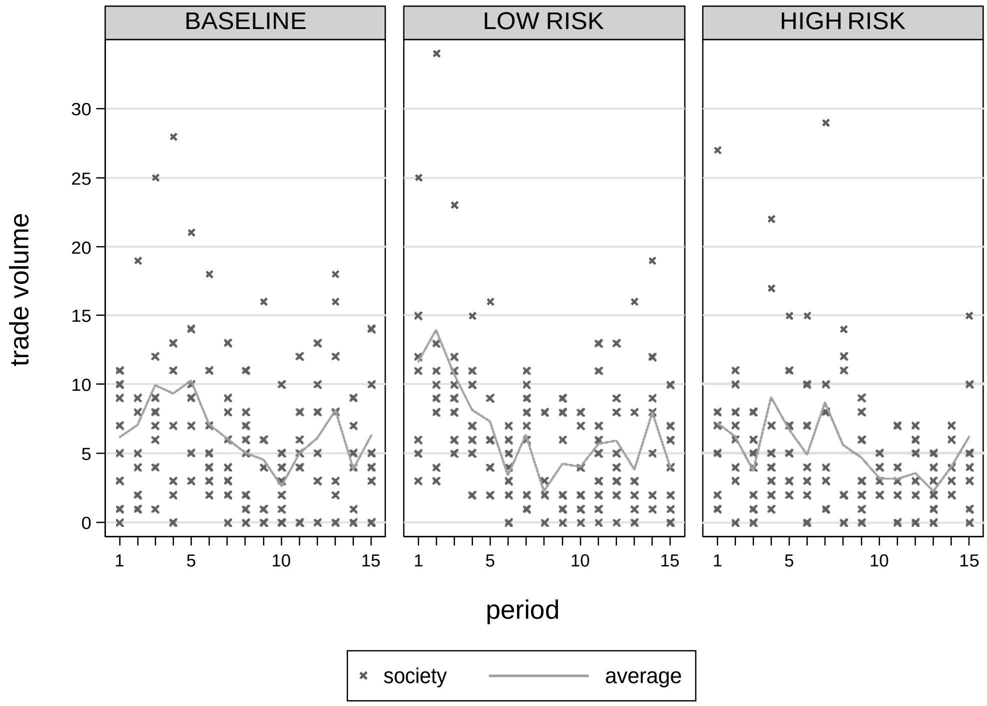
In a secondary market, agents are able to buy and sell certificates at any price, restricted only by their current budget. Figure 3 provides an overview of the respective price dynamics and Figure 4 depicts the trading volumes.

Figure 3. Price dynamics in markets by treatments



Similar to the pattern in unit auction prices, average market prices and price volatility tend to substantially deteriorate over the course of the game for all treatments (Wilcoxon-Sign-Rank test; for *BASELINE* z=2.521 and p=.0117, for *LOW RISK* z=2.666 and p=.0077, for *HIGH RISK* z=2.521 and p=.0117). For trade volumes, the same pattern can be identified as volumes almost halve between the first and second half of the game (Wilcoxon-Sign-Rank test; for *BASELINE* z=1.820 and p=.0687, for *LOW RISK* z=2.547 and p=.0109, for *HIGH RISK* z=2.240 and p=.0251). Table 6 summarizes these findings and shows that there are no statistically significant differences across treatments.

Figure 4. Market volume dynamics by treatment



		BASELINE	*LOW RISK*	*HIGH RISK*
market prices	period<=7	**27.28**	**36.46**	**31.80**
		(7.14)	(14.56)	(13.56)
	period >7	**9.70**	**8.25**	**7.26**
		(1.88)	(3.39)	(3.73)
	overall	**19.41**	**25.30**	**20.06**
		(3.20)	(9.99)	(3.00)
trade volumes	period<=7	**7.53**	**7.56**	**6.73**
		(2.88)	(3.81)	(3.01)
	period >7	**4.95**	**4.54**	**3.89**
		(2.13)	(2.56)	(1.75)
	overall	**6.16**	**6.22**	**5.32**
		(2.51)	(3.19)	(2.00)

Table 6. Price averages and standard deviations of market prices by treatment

Note: Applying a Wilcoxon-Rank-Sum test against *BASELINE* where *, ** and *** indicate p-values smaller than 0.1, 0.05 and 0.01, respectively; standard deviations in parentheses. Unless mentioned otherwise, all calculations and tests are carried out at the society level.

Result 2a: *Average prices in the secondary market for certificates in a TDR system substantially decrease over time after initially exceeding fair values. The underlying risk has no influence on this pattern of price dynamics.*

Result 2b: *Independent of the underlying risk, certificate trade volumes in the secondary market decrease over time in a TDR system.*

It is important to note that prices in the secondary market are substantially higher than the unit auction prices.[2] This finding is somewhat surprising and hints at a persistent distortion in a cap & trade system that leads to strong redistribution effects among agents. As an explanation, one might assume that speculation motives drive prices in the secondary market or that subjects caught up in the action of trading certificates are unable to properly assess price dynamics. However, it appears reasonable to expect that subjects are able to account for

[2] Testing for differences between unit auction and market prices in the first half of the game by applying a Wilcoxon-Sign-Rank test gives z=-3.240 and p=.0251 for *BASELINE*, z=-2.666 and p=.0077 for *LOW RISK* and z=-2.521 and p=.0117 for *HIGH RISK*. For the second half, the test gives z=-1.540 and p=.1235 for *BASELINE*, z=-2.192 and p=.0284 for *LOW RISK* and z=-2.521 and p=.0117 for *HIGH RISK*.

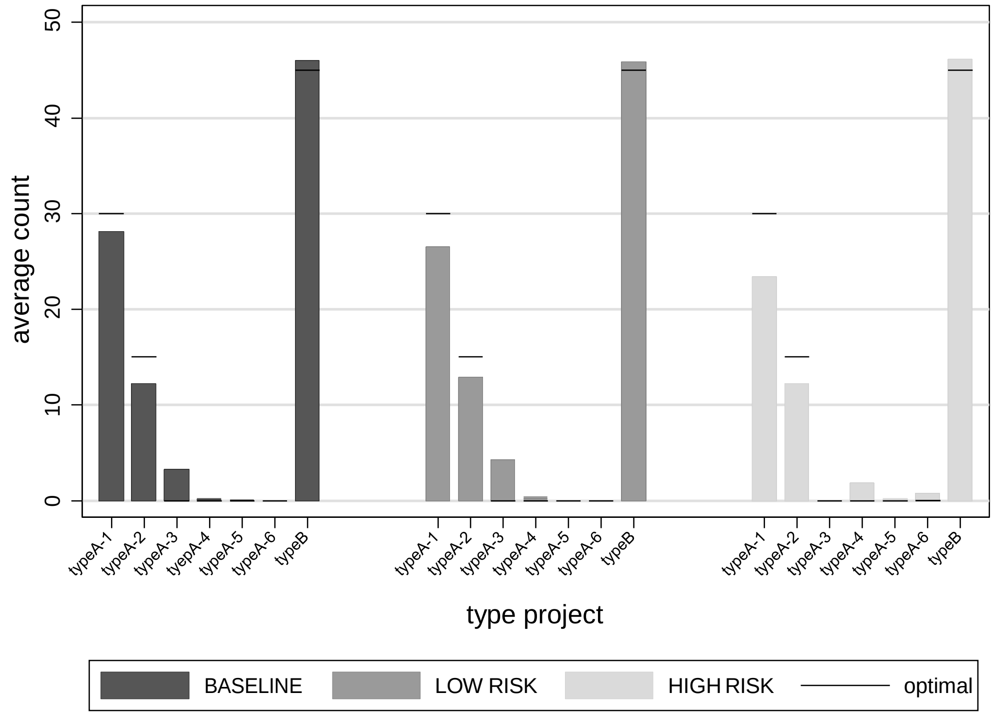
overshooting prices in the secondary market by bidding more in the auctions to gather certificates. Nonetheless, differences remain rather constant over time as for *BASELINE/LOW RISK/ HIGH RISK* market prices in the second half of the game remain about 16%/26%/45% higher than unit auction prices. Another plausible explanation is the endowment effect (Kahneman et al., 1991). This well-established behavioral bias involves agents valuing some good in their possession higher than the same good when they do not possess it, i.e. a persistent divergence of a person's willingness to pay and willingness to accept. Accordingly, certificates acquired in the auction and passing in the possession of a particular agent might be valued at a premium and might thus only be offered at higher prices than those paid in the auctions. Following this interpretation, the persistent divergence of prices does not result from speculation motives, but rather from the behavioral effect of agents perceiving that they should receive a subjectively appropriate compensation for their loss in property.

Result 2c: *Prices in the secondary market persistently exceed unit auction prices, which points to a potentially inherent distortion in TDR systems.*

5.3 Project realizations and land consumption

As outlined in section 3, agents can only carry out one project in each period of Type A or B. Type A projects require the use of certificates and generate certain expected payoffs. Type B projects are of a uniform value, yet their realization does not require certificates. Figure 5 summarizes the average number of projects actually carried out by treatment, as well as depicting the theoretical optimum that maximizes aggregate welfare, which is given at 30 Type A-1 projects, 15 Type A-2 projects and 45 Type B projects per society.

Figure 5. Project realizations by treatment

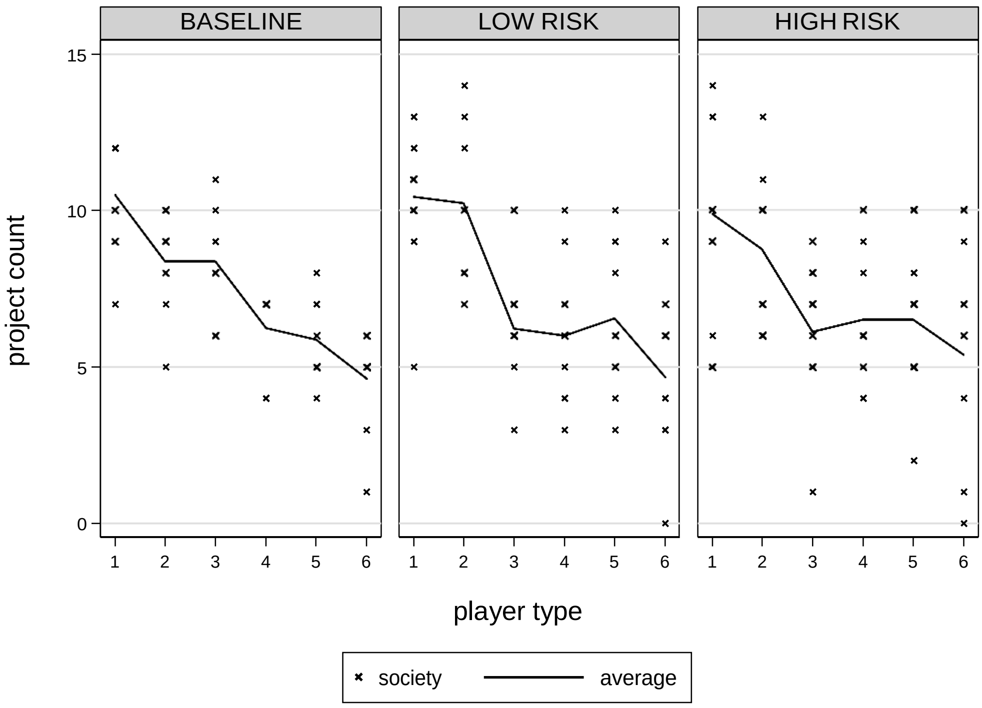


The distribution of project realizations is quite similar for *BASELINE* and *LOW RISK*. By contrast, the realization of Type A-1 projects worth 100ECU is lower in *HIGH RISK*, i.e. there are significantly fewer Type A-1 projects conducted compared to *BASELINE* (Wilcoxon-Rank-Sum test; against *LOW RISK* z=1.179 and p=.2385, against *HIGH RISK* z=2.763 and p=.0057). Overall, almost all certificates are consumed on average; thus, almost the maximum of 45 Type A projects is carried out on average. Consequently, the distribution between project realizations (Type A) and the outside option (Type B) fulfills the expectations induced by the design of the cap & trade system.

Result 3a: *The cap & trade system tends to allocate certificates such that the expected pattern of project realizations and the outside option is established and the objective of reducing land consumption is achieved with near-perfect precision. However, given high risk, the distribution of realized projects shifts towards less valuable projects.*

Another interesting aspect when considering land consumption is given by the distribution of realized projects across the different types of agents. Figure 6 shows the number of realized projects with respect to agent types by treatment.

Figure 6. Distribution of realized projects over player type by treatment



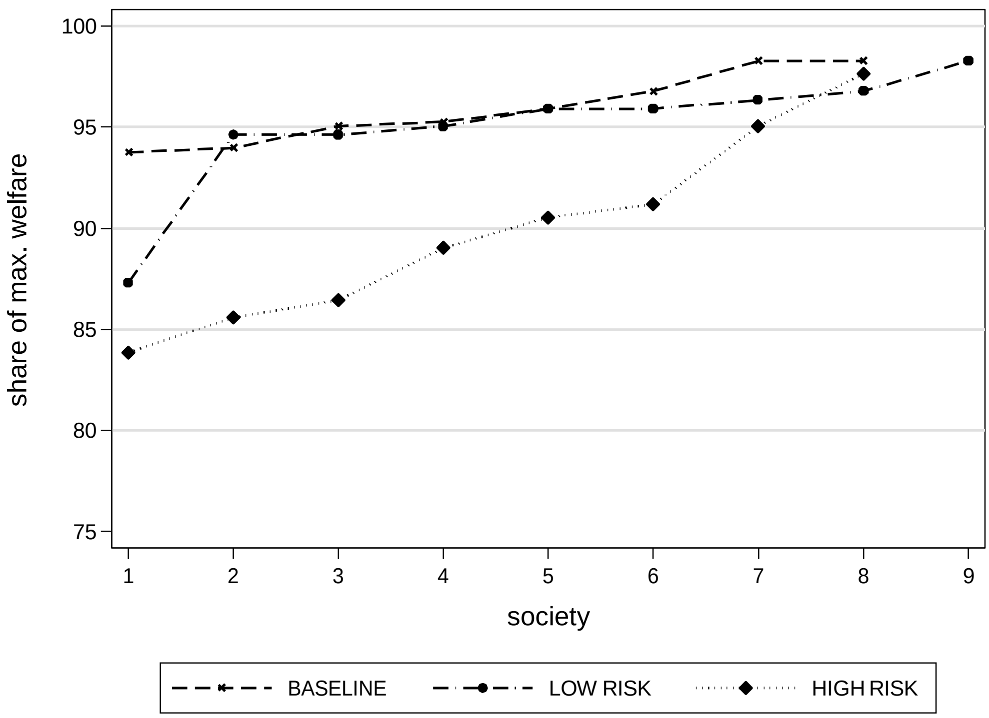
Evidently, there are no substantial differences across treatments, since a pattern of decreasing project realizations along with the "size" of the agent emerges for all levels of underlying risk. The number of certificates grandfathered seems to be the predominant factor in determining which agents realize projects. The redistribution of certificates resembles the basic pattern expected from the design of the cap & trade system, although this relation is somewhat weaker once there is risk in project revenues as the heterogeneity in realized projects conditional on agent type tends to increase.

Result 3b: *The number of realized projects depends on an agent's endowment in land consumption projects and her number of certificates grandfathered. This relation weakens with increasing underlying risk.*

5.4 Efficiency and welfare analysis

Finally, we consider the overall efficiency and the resulting welfare consequences of our treatments. Recall that the only potential source of inefficiency in a cap & trade system lies in the under-consumption of certificates or the realization of less valuable projects caused by a non-optimal allocation of certificates. As stated in Result 3a, the realization of Type A-1 projects is lower when underlying risk is high. Figure 7 illustrates the consequences of such inefficiencies in the distribution of realized projects by comparing the share of the maximal feasible welfare achieved by each society by treatment, whereby societies are ranked in terms of their level of efficiency.

Figure 7. Share of maximum welfare over societies by treatment



While there are no substantial differences between *BASELINE* and *LOW RISK* (Wilcoxon-Rank-Sum test; z=0.291 and p=.7713), societies in *HIGH RISK* perform inferiorly as the second best society only slightly outperforms the weakest society of *BASELINE* (z=2.472 and p=.0134).

Result 4: *A TDR system to reduce land consumption achieves lower levels of aggregate welfare when the associated risk in revenues of land consumption projects is high. This is due to an inefficient distribution of certificates, which leads to a realization of projects with inferior value.*

6. Discussion and conclusion

In this study, we suggest that experimental empirical evidence can contribute to studying the determinants of successful TDR systems by providing complementary insights to previous theoretical- and case study-based investigations. This methodological approach to the question of an optimal design of TDR systems necessarily has certain restrictions. For instance, given that laboratory experiments require a number of assumptions and simplifications to achieve a high degree of internal validity and understanding among participants, not all complexities of real-world applications of TDR can be implemented. Similarly, student participants might act differently than actual agents in charge of land use decisions. While both of these aspects place certain limitations on the direct applicability of our results, we nonetheless argue that the counterfactual results of experimental studies providing ceteris paribus analyses of the impact of core parameters to a system of TDR yield valuable insights unattainable by field data. We suggest that the uncertainty associated with obtaining, trading and using TDR constitutes is one of these key features in land use decisions and needs to be taken into account when considering policy options and institutional designs. Therefore, we use a novel experimental design that captures the core aspects of a TDR system. Two additional treatments are conducted to assess the impact of varying degrees of investment risk. Our experimental setting enables us to observe the individual and overall market effects of the treatment variable and formulate policy implications for the design of TDR systems in economic contexts associated with different degrees of risk.

Overall, three distinct behavioral patterns emerged in our study. First, higher levels of investment risk reduce the average prices paid in auctions, leading to lower levels of redistribution from agents to the auctioning institution. Second, prices for certificates in auctions and the secondary market persistently diverge regardless of treatment conditions. This result has been shown in previous experimental studies on TDR (Meub et al., 2017, 2017, 2016) and can be interpreted as resulting from the endowment effect (Kahneman et al., 1991). While more pronounced for conditions of higher risk, this effect adds to the redistribution of income among agents. Third, participants' risk preferences have a substantial impact on the project realizations, whereby risk-loving players who might control fewer valuable projects tend to buy certificates from risk-averse players who might control more valuable projects. This precludes the realization of the most valuable projects and the allocation of TDR becomes inefficient. Accordingly, certificates are partly reallocated according to risk preferences – i.e. based upon their expected utility – whereby they cease to be fully allocated according to the expected value of projects, which would be the aggregate welfare maximizing condition.

At an aggregate level, the TDR system consistently proves efficient in situations of low and no risk in future revenues of land consumption projects. Certificates are reallocated efficiently to agents who can realize the most valuable projects; while prices and price volatility are initially high, they gradually decrease; trade volumes react similarly. There is a persistent gap between certificate prices in the auctions and the secondary market, which this does not affect overall welfare. For conditions of high investment risk, welfare substantially decreases due to an inefficient allocation of certificates. Auction prices are consistently lower, which reduces the redistribution in favor of the auctioneer. Trading volumes and prices in the secondary markets are largely unaffected by conditions of higher risk in land consumption projects.

Two core implications can be derived from a policy perspective. Primarily, it has been shown that a TDR system is an efficient mechanism for reallocating development rights to the most valuable building projects for conditions of low and no risk in revenues of land consumption projects. Despite overshooting at first, prices gradually decrease. The divergence of auction and trading prices leads to strong redistribution effects among agents yet has no overall welfare implications. Secondarily, when considering situations of higher investment risk, certificates are allocated to risk-loving agents who potentially do not control the most valuable building projects. Particularly in situations in which the profitability of potential building projects available to participants in a TDR system is very heterogeneous and investment risks are high, the welfare losses due to risk-related behavioral effects may become substantial. Accordingly, TDR might not be the best policy choice for these particular economic contexts.

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Appendix: Instructions for the *BASELINE* treatment. The differences for *LOW/HIGH RISK* are indicated in braces.

OVERVIEW OF THE GAME

You can earn money in this game by realizing projects and trade with certificates. At the beginning, you will be randomly assigned to a group of 6 players, which will remain constant during the 15 periods of the game. All prices and values in the game will be paid in ECU with up to two positions after decimal point. 100 ECU convert to 1€ for your payoff.

Projects

Overall, each player has 30 projects of **Type A** and 15 projects of **Type B**. Both types of projects have different values, which are shown in this table:

Type of project	Project value (in ECU)
A	0 bis 100
B	10

{Note: The table does not apply to *BASELINE*. The numbers for low and high refer to *LOW* {*HIGH*} *RISK* respectively. The numbers for medium apply to both treatments.}

Type of project	Potential project value (in ECU)		
	low	medium	high
A1	50 {-100}	100	150 {300}
A2	40 {-80}	80	120 {240}
A3	30 {-60}	60	90 {180}
A4	20 {-40}	40	60 {120}
A5	10 {-20}	20	30 {60}
A6	0	0	0
B	10	10	10

In each period, only one project can be realized. {*BASELINE*: Before the game starts, the values of all Type A projects will be assigned and shown to you.} All players are assigned different Type A projects. {*LOW/HIGH RISK*: Type A projects have variable project values, which lead to low, medium or high payoffs, each with the same probability (1/3). Which project values have realized will be shown to you at the end of the game.}

Certificates

For the realization of Type A projects, you need 8 certificates each, Type B projects do not require certificates. Certificates are assigned to you at the beginning of each period and auctioned. Additionally, certificates can be traded among the players. In the game, you receive an endowment of 700 ECU which you can use to buy certificates at the auction and from the other players. You can also sell certificates and thus increase your payoff.

Your payoff

The payoffs you receive in the course of the game, as well as the sum of all {*LOW/HIGH RISK*: actually} realized projects add up to your final payoff. Further, a basic payoff of 400 ECU will be added.

COURSE OF THE GAME

Each of the 15 periods follows an identical course, which consists of three phases.

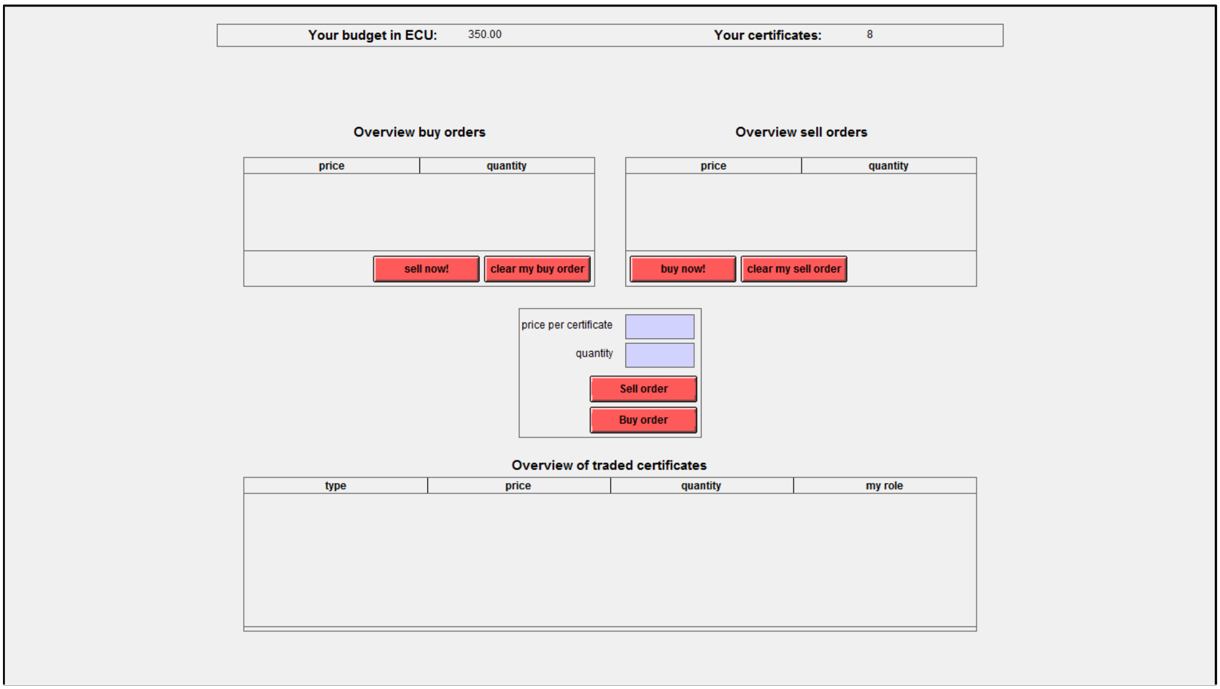
Phase 1: Allocation and auctioning of certificates

At the beginning of each period, 12 certificates are allocated. The number of certificates a player receives is determined randomly at the beginning of the game and does not change during the game.

Additionally, after the allocation, 12 certificates are auctioned. Depending on your current funds, you can bid for a number of certificates of your choosing at a unitary price. The 12 highest bids will receive the certificates to the price of the lowest successful bid.

Phase 2: Trading of certificates

Following the allocation and auctioning, this phase lets you trade with the other five players, i.e. buy and sell certificates. You can offer a trade yourself and also accept offers from other players. To clarify this, you see the respective screen of the trading phase below:



Offering a trade

In the lower box, you can enter a price (in ECU) and the respective amount of certificates that you would like to buy.

- **By clicking "searching"**, all players are shown your buying desire in the left box. Once another player agrees to your offer, you will receive the respective number of certificates. The total value (price x quantity) of the trade will be withdrawn from your funds.
- **By clicking "offering"**, all players are shown your sell offer in the box on the right. Once another player accepts your offer, you sell the respective number of certificates. The total value (price x quantity) of the trade will be added to your funds.

Accepting another player's offer

In the boxes on the right and left side, you can see all current buy and sell offers for certificates. If you choose an offer and click on "sell now!" or "buy now!", you make the trade with the respective player.

You are allowed to trade as often as you please. You can also make multiple sell and buy offers at the same time. The trading phase ends automatically once **2 minutes** have passed.

Phase 3: Realizing projects

In the third phase of the game, you can realize one of your projects. You will receive the respective payoffs ({*LOW/HIGH RISK*: actually realized} project value in ECU) at the end of the game. After the third phase, the next period begins. Certificates that are not used in one period can be saved for subsequent periods. Note, however, that you will not receive a payoff for certificates that remain unused until the end of period 15!

Workingpaper Nr. 5

THE ROLE OF COMMUNICATION ON AN EXPERIMENTAL MARKET FOR TRADABLE DEVELOPMENT RIGHTS

von

Dr. Till Proeger, Dr. Lukas Meub und Prof. Dr. Kilian Bizer

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The role of communication on an experimental market for tradable development rights

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Abstract: Tradable development rights (TDR) are discussed as a means of containing urban sprawl in numerous countries. Despite its theoretical superiority in ensuring an efficient redistribution of planning rights, its applicability is concerned with several open questions and potential problems. Introducing a novel experimental setting, we simulate a cap & trade TDR scheme and investigate the effects of communication, an aspect typically assumed to be irrelevant by theory. We consider communication among individual participants competing in a TDR system and team decision-making facilitated by face-to-face communication. We find the system to be quite efficient, despite overshooting certificate prices particularly in the beginning for both initial issuance in auctions and the secondary market. Communication significantly reduces auction prices, leading to substantially less income redistribution from participants to the auctioneer. This effect is explained by participants' improved understanding of the cap & trade system when communicating; despite participants' attempts, they fail to establish collusion. Team decision-making is not only shown to reduce overshooting prices; moreover, it also improves the system's efficiency. These results are interpreted as emphasizing the efficiency and political feasibility of TDR schemes when including communication among its participants.

Keywords: cap & trade, collusion, communication, economic experiment, land consumption, tradable planning permits

JEL Classification: C91; C92; D8

1. Introduction

Urban sprawl and its adverse ecological consequences have long been addressed by researchers and policy-makers. Among the regulatory options to foster a sustainable land use discussed in recent years, tradable development rights (TDR) are increasingly considered in different countries as a viable instrument achieving reductions in land consumption while allowing for the realization of the most profitable projects (van der Veen et al., 2010).[1] As with similar market-based instruments, TDR are expected to be the superior regulatory instrument for implementing constraints on land consumption. Assuming floating prices and an effective system of trading and issuing TDR, planners can reduce land consumption with near-perfect precision while reallocating development rights to the most valuable projects (c.p. Thorsnes and Simons, 1999; for more recent theoretical contributions, see e.g. Nuissl and Schroeter-Schlaack, 2009; Ward, 2013; Vejchodska, 2015).

While several studies have provided surveys on the success and problems of TDR schemes, particularly for the United States (e.g. Kaplowitz et al., 2008; Pruetz and Standridge, 2009; Tan and Beckman, 2010; Chan and Hou, 2015), their ability to provide generalizable policy implications for different national and institutional contexts remains limited (Bengston et al., 2004; Kopits et al., 2008). As a promising complement to these case-study based surveys, it has been suggested to run laboratory experiments investigating more general behavioral patterns and testing specific policy instruments (Greenstone and Gayer, 2009), e.g. for the design of CO_2 cap & trade schemes (c.p. Convery, 2009 and Grimm and Illieva, 2013).[2] Despite the potential value for improving the design of TDR schemes, few studies capture TDR experimentally; for instance, Henger (2013) compares student and professional TDR

[1] TDR are predominantly discussed by environmental economists and planners in economically developed nations such as Australia (Harman and Choy, 2011), China (Wang et al., 2009), Germany (Henger and Bizer, 2010), Italy (Micelli, 2002), the Netherlands (Janssen-Jansen, 2008), Switzerland (Mengini et al., 2015). In Germany, the discussion on TDR has increased following the federal government's commitment to drastically reduce land consumption within the next years; consequently, several large-scale trials for a nation-wide system of TDR have been conducted. The United States, in turn, have been using TDR on a broad scale since the 1970s in more than thirty states (see e.g. Pruetz, 1997 for an overview).

[2] The discussion regarding the application of experimental evidence to the institutional design in different domains of policy-making has been an ongoing debate for several years, with numerous authors arguing for a pragmatic approach of using behavioral evidence as a complement to other forms of empirical and theoretical evidence. For an introduction to the discussion, see e.g. Falk and Fehr (2003), Falk and Heckman (2009), Madrian (2014) and Chetty (2015).

trading, while Meub et al. (2016) investigate the resilience of a TDR system against exogenous shocks.

Building on these studies, we argue that the current experimental approaches have an inherent limitation similar to that of theoretical studies, namely the assumption that agents decide autonomously without communicating and potentially coordinating with other agents in the TDR system. This assumption might be unrealistic; indeed, we would suggest that it is unlikely for individuals charged with making land use decisions within a system of TDR to do so in complete isolation from other officials. Rather, it can be expected that they are members of networks at regional, state or national levels, communicate extensively about the decisions taken in the TDR system and build up long-term relationships, thus potentially making arrangements that could distort or improve market outcomes. It is therefore an open question whether communication among participants of a TDR scheme could lead to a failure in the market's capability to efficiently reallocate certificates or even increase the system's efficiency. Both outcomes would have substantial implications for the political feasibility of TDR schemes and the viability of its theoretical assumptions.

To determine the impact of communication, we build on an experimental design simulating a comprehensive TDR scheme, which allows us to measure subjects' reactions to variations of its core parameters. We investigate two prominent mechanisms of communication that potentially have a strong impact on the functioning of a TDR mechanism. Firstly, communication among all agents within a TDR market is introduced to determine whether agents establish cooperation - e.g. by collusive behavior in the auction of certificates - during their repeated interaction. Since collusion has been identified as a potential source of inefficiency in CO_2 cap & trade systems (Whitford, 2007; Ehrhart et al., 2008), its prevalence in TDR markets might similarly reduce the system's feasibility. Secondly, we investigate the effects of communication within small groups of participants representing a single agent to determine whether small group decision-making increases the overall efficiency in the TDR market. Numerous experimental studies have shown that intra-group communication leads to more rational decision-making overall (Kugler et al., 2012; Charness and Sutter, 2012). If this finding transfers to TDR schemes - where extensive communication within organizations responsible for obtaining, trading and using TDR can be assumed - specific problems of TDR systems emphasized in previous experimental studies might be mitigated, such as overshooting prices (e.g. Meub et al., 2016).

The remainder of this paper is structured as follows. The subsequent section reviews the related literature, before section three explains the experimental design and the underlying theoretical model. Section four presents our findings and section five concludes.

2. Literature review

To date, TDR systems have primarily been considered from a case-study perspective, yielding broad evidence on factors determining the success factors of TDR at a regional political level, such as strong demand for additional areas of development or regionally customized receiving areas (Pruetz and Standridge, 2009). These policy-oriented considerations are based upon a large body of review studies covering fairly heterogeneous implementations of TDR systems, particularly in the United States. Therefore, studies using qualitative indicators (e.g. Santos et al., 2015; Harman et al., 2015; Kaplowitz et al., 2008; Pruetz and Standridge, 2009; Machemer and Kaplowitz, 2002; Danner, 1997) as well as reviews using quantitative measures (Menghini et al., 2015; Kopits et al., 2008; Lynch and Musser, 2001; Lynch and Lovell, 2003) have been presented. While these studies have led to the identification of several determinants for the successful regional implementation of TDR, we argue that these conclusions are necessarily tied to the respective national and institutional contexts.

Complementary to the reviews on local implementations of TDR schemes, laboratory experiments can be used to test specific institutional parameters relevant in the context of land use decisions. Analyzing counterfactual situations with or without a specific regulation (Charness and Fehr, 2015 and Santos, 2011), a limited number of studies have provided initial laboratory evidence. Testing the general applicability of results obtained by observing student participants to land use decisions, Henger (2013) compared the performance of students and regional planners in a TDR scheme, yielding the result that both groups achieve efficient reallocations of development rights overall. Meub et al. (2014) extend this basic setting and investigate the influence of political business cycles on the efficiency of TDR schemes, pointing to potential distortions in TDR schemes due to politicians' self-serving incentives. Meub et al. (2015) compare different mechanisms of issuing development rights, finding that auctioning introduces several sources of inefficiency, making grandfathering the superior institutional choice from a welfare perspective. Proeger et al. (2015) have considered the effects of sustained high investment risk, finding that TDR schemes lose efficiency when confronted with higher levels of risk. Finally, Meub et al. (2016) investigate the resilience of a

TDR scheme to exogenous economic shocks, finding that the system compensates shocks fairly well.

While several core factors regarding TDR schemes have been investigated in laboratory settings, it is important to emphasize that the experimental designs uniformly assume individual decision-making, excluding interaction among agents. Since this should be considered an overly strict assumption for the study of behavioral patterns in TDR systems, previous results might only insufficiently represent the actual decision situation. Rather, the broad results of economic group research should be taken into account, pointing out that decisions taken by groups are regularly closer to game-theoretically optimal behavior across a wide range of economic contexts (Kugler et al., 2012; Charness and Sutter, 2012). Overall, three distinct reasons are given concerning why groups show superior rationality when compared to subjects in settings of individual decision-making. First, teams have higher cumulated cognitive abilities than individuals, which increases the likelihood of reaching better decisions. Examples of this include the Beauty-Contest game (Kocher and Sutter, 2005), urn experiments on first-order stochastic dominance (Charness et al., 2007) or the Linda Paradox game, involving the correct interpretation of probabilities (Charness et al., 2010). Second, teams anticipate the behavior of other persons more efficiently, which enhances their ability to derive better responses conditional on other players' potential decisions. For instance, this is shown in the limit-pricing game (Cooper and Kagel, 2005) or simple two-player games with unique pure-strategy, Pareto-inefficient Nash equilibria (Sutter et al., 2010). Third, groups have been shown to develop stronger self-interested preferences than individuals, e.g. shown in the trust game (Kugler et al., 2007), the centipede game (Bornstein et al., 2004) or prisoner's dilemma games (Charness et al., 2007). This is explained by their reduction of social considerations through establishing in-group norms for maximizing the collective income (Charness and Sutter, 2012). Overall, groups have been shown to be cognitively superior, more anticipatory and less restricted by social concerns, bringing them closer to rational decision-making. Accordingly, introducing communication and the ability to cooperate within a TDR scheme might substantially alter the results presented in previous experimental implementations of TDR, such as overshooting prices or endowment effects.

Since cooperation might enhance rational decision-making in a TDR scheme, this might lead to collusive efforts aimed at reducing the price of certificates paid to the auctioneer. This strategic behavior is shown in several theoretical and experimental studies as a consequence of a broad range of auction mechanisms. While it is accepted that the auction design should reduce the likelihood of collusion among bidders (Whitford, 2007), the detrimental effect of communication and collusion has been shown for different auction formats. Using a theoretical model, this problem is shown for the EU-ETS[3] system by Ehrhart et al. (2008). Burtraw et al. (2009) report experiments on collusion for different formats of auctions, in which subjects were allowed to use chat communication, which lead to lower prices in the auctions and a redistribution of revenues from the auctioneer to participants. Mougeot et al. (2011) show that uniform price auctions with sealed bids maximize the auctioneer's income once speculators are included. However, there is a tradeoff between higher revenues from auctions with speculators and the efficiency of the respective auction. Llorente-Saguer and Zultan (2014) consider the effects of first- and second-price auctions on collusion, showing that - contrary to theoretical predictions - there are identical levels of collusion and losses in efficiency. Most recently, Matousek and Cingl (2015) have shown that communication leading to collusion can also increase the overall efficiency in multi-object auctions. Overall, collusion is considered a substantial problem that potentially distorts the functioning of cap & trade systems as intended by regulators. Therefore, an experimental test involving a TDR scheme incorporating the element of communication is required to estimate the potential losses in efficiency and auctioneer revenues, as well as assessing whether a different institutional design is required to ensure an efficient reallocation of development rights.

[3] The EU-ETS system is used to trade CO_2 certificates since. Despite its numerous problems at present, its introduction can be considered a successful example for using both theoretical and experimental evidence to inform policy-making, as many institutional choices have been influenced by previous behavioral studies (Convery, 2009 and Grimm and Illieva, 2013 provide introductions to the literature).

3. Experimental design

3.1 A laboratory implementation of TDR

For our experimental investigation, we choose a fairly universal design of TDR that transfers to various institutional settings. Our experimental approach builds on previous laboratory studies of TDR and those simulating cap & trade systems for CO_2 emissions whereby experimental participants simulate economic agents that might represent municipalities, firms or individuals involved in a cap & trade system on land consumption.

Subjects are required to accumulate certificates to conduct building projects associated with land consumption. Due to the limited number of certificates issued by public authorities, not all desired projects can be realized; rather, an efficient TDR system reallocates certificates to the agents endowed with the most valuable projects.

The issuance of certificates in each period is conducted in two ways: first, half of the certificates are allocated among the players for free ("grandfathering"); and second, there is an auction for the remaining half of the certificates. Consequently, each player receives a distinct number of certificates and can bid on additional certificates in the ensuing auction. Subsequently, there is a trading phase, during which all players can buy and sell certificates; optimally, this leads to a redistribution of certificates to the players endowed with the most profitable projects, who consequently show the highest willingness to pay.

While the process of accumulating certificates and conducting projects is identical for all players, all agents have different characteristics, namely a different endowment with building projects and a different number of certificates grandfathered. This heterogeneity of agents simulates the different sizes of economic agents within a TDR scheme that might well be reflected in the grandfathering of certificates and the diverging availability of projects with a varying profitability.

While the basic setup implemented in our laboratory study simulates a system of TDR without any interaction among agents as a benchmark, our two additional treatments capture the element of communication. We assume that communication within networks of public or private participants in a system of TDR necessarily leads to a broad variety of arrangements that potentially undermine the efficient functioning of TDR. Since economic agents communicating openly have been shown to reach superior cognitive performance, to be more anticipatory of other players' behavior and less restricted by fairness norms than individual players, this may lead to quite different outcomes of a TDR scheme. We test the relevance of this effect by implementing two distinct communication channels prevalent in real-world land use decisions, namely immediate communication and cooperation within a small group representing a single agent and communication among all participants on a market, simulating broader networks, are implemented as separate treatments.

3.2 An outline of the game

The experimental design used in this study extends previous designs used e.g. by Meub et al. (2016). All experimental subjects are matched to markets of six players, which remain constant throughout the fifteen periods of the game. Subjects are endowed with different projects, whose realization generates payoff after the game's final period. This design feature simulates the duration of building projects and the resulting delay in the realization of respective payoffs. Furthermore, payoff can be generated by trading certificates on the secondary market. There is a starting endowment of 700ECU independent of player types.

Subjects are randomly assigned a "player type", which determines the number and type of available projects and the number of certificates grandfathered in each period. These different characteristics simulate that agents are likely to have different "sizes", i.e. possessing more or fewer potential building projects, having higher political clout or a greater market power. The assigned player types remain constant during the game. The different endowments for the six players per market are provided in table 1.

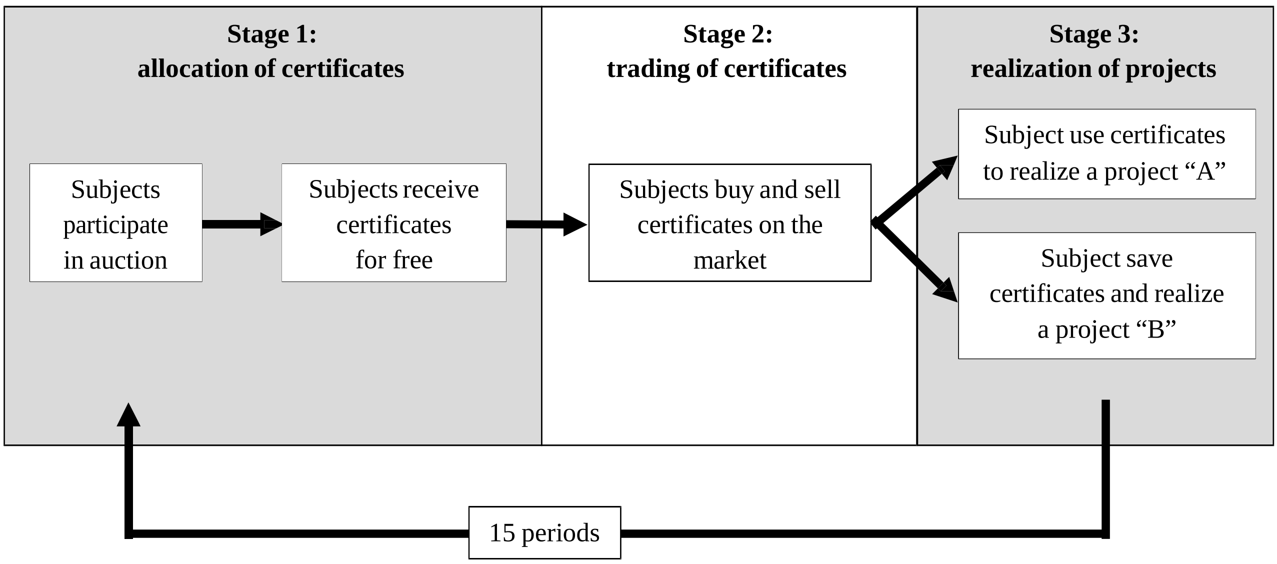
There are main projects denominated "Type A", whose realizations yield between 0- and 100ECU, whereby 100ECU converts to 1€. Subjects need to acquire eight certificates to conduct one of the six different Type A projects. Thereby, regardless of its value, each project type requires the same number of certificates. This assumption is made to increase the comprehensiveness of the game for the participants. The secondary project type is denominated "Type B", it has a uniform value of 10ECU and can be considered subjects' outside option when an insufficient number of certificates were accumulated in the respective period. Note that only one project can be conducted by each subject in each period. Hence, a total of fifteen projects can be realized by each subject during the game. The different projects are shown below in table 1.

project	**type**	A-1	A-2	A-3	A-4	A-5	A-6	B			
	value	100	80	60	40	20	0	10			
	certificates	8	8	8	8	8	8	0			
									total	**certificates period (total)**	
										#grandfathered	#auctioned
agent	**1**	10	8	6	4	2	0	15	**45**	4(60)	-
	2	8	10	6	4	2	0	15	**45**	3(45)	-
	3	6	8	10	4	2	0	15	**45**	2(30)	-
	4	4	6	8	10	2	0	15	**45**	1(15)	-
	5	2	4	6	8	10	0	15	**45**	1(15)	-
	6	0	2	4	6	8	10	15	**45**	1(15)	-
	total	**30**	**38**	**40**	**36**	**26**	**10**	**90**	**270**	**12(180)**	**12(180)**

Table 1. Player and project types and certificates allocated.

Each period comprises three stages; an overview is provided in figure 1.

Figure 1. Overview of the game's three stages.



Stage one involves the issuance of certificates by the auctioneer and the resulting accumulation by subjects. As shown in table 1, 12 of the 24 certificates issued in each period are auctioned in a uniform price auction with sealed bids, in which bids are ranked according to price. The lowest bid granted certificates subsequently determines the uniform price for all certificates auctioned in the respective period. The other half of the certificates are grandfathered to subjects according to their player type.

Stage two enables subjects to trade certificates in a simple double auction market for three minutes. There are no trade limits and no transaction costs. Subjects are, however, restricted by their budget constraint, which precludes borrowing to buy certificates.

Stage three allows subjects to realize one Type A project if they have accumulated enough certificates or one Type B project, requiring no certificates. Only one project can be realized per period, whereby the respective revenue is paid after the final period.

Our treatments introduce two distinct forms of communication into this basic framework. The treatments are fully identical to our benchmark treatment (*BENCHMARK)*, with the exception of the two modes of communication, whereas all other features of the game remain constant. Please note that *BENCHMARK* is also used as a baseline in Meub et al. (2016).

The first treatment (*CHAT*) introduces communication through a chat box implemented in z-Tree (Fischbacher, 2007) among all six market participants. In all stages of the game, the chat box enables the unrestricted communication among subjects.

In the second treatment (*TEAM*), teams of two subjects are randomly matched and decide as a single agent during the game. Since decisions are taken as a single player at one computer, the communication is conducted face-to-face and unanimous decisions are required. The payoff generated during the game is paid to each of the two players. Since the number of agents in each market remains constant, there are now twelve subjects, corresponding to six team agents.

3.4 Experimental procedure

All treatments were conducted in the Laboratory for Behavioral Economics at the University of Goettingen using z-Tree (Fischbacher, 2007) and ORSEE (Greiner, 2004). There were 48/24/48 participants for *BASELINE/CHAT/TEAM*. A common understanding of the game was ensured through prior control questions. Subjects were only allowed to participate in a single session. The instructions for the game were in German and can be obtained from the authors upon request, while an English translation is documented in the appendix. The sessions took 80 minutes on average. The average payment was 14.76 €, including a fix amount of 4€. Participants were recruited from various academic disciplines, comprising undergraduate and graduate students.

3.5. Expected behavior

The setup of the game incentivizes all player types to conduct exclusively Type A projects. Without a cap, 6 Type A projects would be realized by the 6 agents of a market in all 15 periods, which would result in a total of 90 Type A projects being realized. Introducing the cap on land consumption restricts the realization of Type A projects in each market by 50%. As each Type A project requires 8 certificates, 24 certificates are issued in each period to implement this cap on land consumption.

We derive the expectations about the prices of certificates by calculating agents' willingness to pay (WTP). The most valuable Type A projects generate a payoff of 100ECU. Taking into account the outside option of realizing Type B projects paying 10ECU, the WTP for one certificate for an agent endowed with a Type A-1 project is given by (100ECU-10ECU)/8=11.25ECU. The same procedure can be applied to Type A-2 projects, which gives a WTP of (80ECU-10ECU)/8=8.75ECU. No further calculations are needed as it is not expected that Type A-3 projects worth 60ECU are realized, given the overall cap of 45 Type A projects and the aggregate endowment of a market with 30 Type A-1 and 38 Type A-2 projects (cp. table 1). Overall, assuming unanimously optimal decision-making, we expect prices not to exceed 11.25ECU and not to fall below 8.75ECU.[4] Over the course of the game, we expect (for each market) all 30 Type A-1 projects to be realized, as well as 15 Type A-2 projects and 30 Type B projects.

Welfare is calculated by the aggregate value generated by realized projects, whereby we do not discriminate between the respective income of the auctioneer and the agents. Hence, we consider payments in the auction merely as a redistribution of income. The efficiency of the cap & trade system might only be distorted when certificates are not allocated optimally - i.e. not the most valuable projects are realized - or when they are forfeited at the end of the game. Nonetheless, the desirability of a cap & trade system as a regulatory instrument might be driven by the expected redistribution of income. Particularly the distribution of income between land consuming agents and the auctioneer might substantially determine the political feasibility of this instrument. In our framework, certificates should be valued between 11.25ECU for Type A-1 projects and 8.75ECU for Type A-2 projects, which allows us to derive the expected income for the auctioneer when assuming that two-thirds of the total 180

[4] Please note that agent are not informed on the actual distribution of projects and their respective values and therefore prices might well exceed 8.75ECU, which would be the fair price under full information and perfect foresight.

certificates auctioned throughout the game (12 certificates in each of the 15 periods) are actually sold at 11.25ECU and one-third at 8.75ECU. The fractions are deducted from the share of the specific project types that we expect to be realized under the cap regulation, i.e. 30/45 Type A-1 projects and 15/45 Type A-2 projects.

Table 2 outlines our expectations when considering optimal behavior by all agents. These expectations represent the efficient outcome that might be achieved by the cap & trade system.

project	**type**	A-1	A-2	B	
	value	100	80	10	
	certificates	8	8	0	
					total
land consumption	**# realizations**	30	15	45	**90**
wealth	**total value**	3000	1200	450	**4650**
certificates	**# bought**	120	60	0	**180**
	# free	120	60	0	**180**
income	**agents**	1650	675	450	**2775**
	auctioneer	1350	525	0	**1875**

Table 2. Theoretical predictions for an efficient cap & trade regulation

It should be noted that all expected results derived are based on the assumption of agents with identical cognitive abilities and understanding of the game. Speculation motives and path dependencies are excluded from our consideration and we assume that agents are capable of an ex ante evaluation and optimal decision-making, while expecting that all others have the same capabilities. Although we expect some of these assumption to fail when observing actual behavior in our experiment, the expected results still define a benchmark that allows appropriately interpreting our results, given that distortions can only be defined as systematic deviations from an otherwise efficient system if there is a benchmark representing optimal behavior.

Behavior in CHAT

In *CHAT*, all agents within a market can communicate. This treatment condition does not alter any expected behavior derived above as it does not affect agents' WTP. Overall, communication is nothing more than cheap talk and – from a rational agent's perspective – successful collusive behavior should not occur in the first place.

However, one might expect collusive behavior at the expense of the auctioneer, which might be built up during the fifteen periods of the game. Without communication, the understanding of being rivals competing for the accumulation of certificates and the realization of building projects might be predominant. Introducing communication might lead agents to understand each other in terms of potential partners with whom they should cooperate within a framework dominated by the auctioneer. However, there is no possibility to punish defective behavior and sealed bids in the auction cannot be directly observed. If agents agree upon a unit price and give identical bids, the beneficiaries of the auction are determined randomly. An agent who did not receive any certificates might feel betrayed as there is no chance to verify whether all the other agents had conformed to the agreement; thus, collusive behavior can easily break down. Nonetheless, the transmission of some information through chat communication among the competing agents can be expected. Consider some agent proposing to agree upon a unit price for the auction. This price simultaneously serves as a benchmark and might convey information about appropriate certificate pricing, which might be particularly relevant for subjects of limited cognitive abilities and imperfect understanding of the game. These considerations illustrate some potential behavioral reactions to chat communication among competitors. Therefore, our treatment *CHAT* can be characterized as being somewhat explorative and potential observations become interesting when abstracting from perfect rational behavior.

Behavior in TEAM

Having two-subject teams decide does not change our theoretical expectations, at least if one assumes that all participants fully understand the game with perfect foresight and following optimal behavior. However, economic small group research has emphasized the superiority of teams compared to individuals in intellective tasks (Kugler et al., 2012, Charness and Sutter, 2012), thus rehabilitating the expectation of rational behavior to some degree. In our setting, this superiority of small group decision-making might lead to prices closer to fair values. Hence, certificates might be reallocated more efficiently, i.e. according to WTP derived by projects' values and not according to agents' understanding of the game and the resulting ability to deduct fair prices. Overall, the efficiency of a cap & trade system to constrain land consumption might thus work more efficiently, although the effect on income distribution among agents and between agents and the auctioneer remains an open question, which will be addressed by analyzing our data.

4. Results

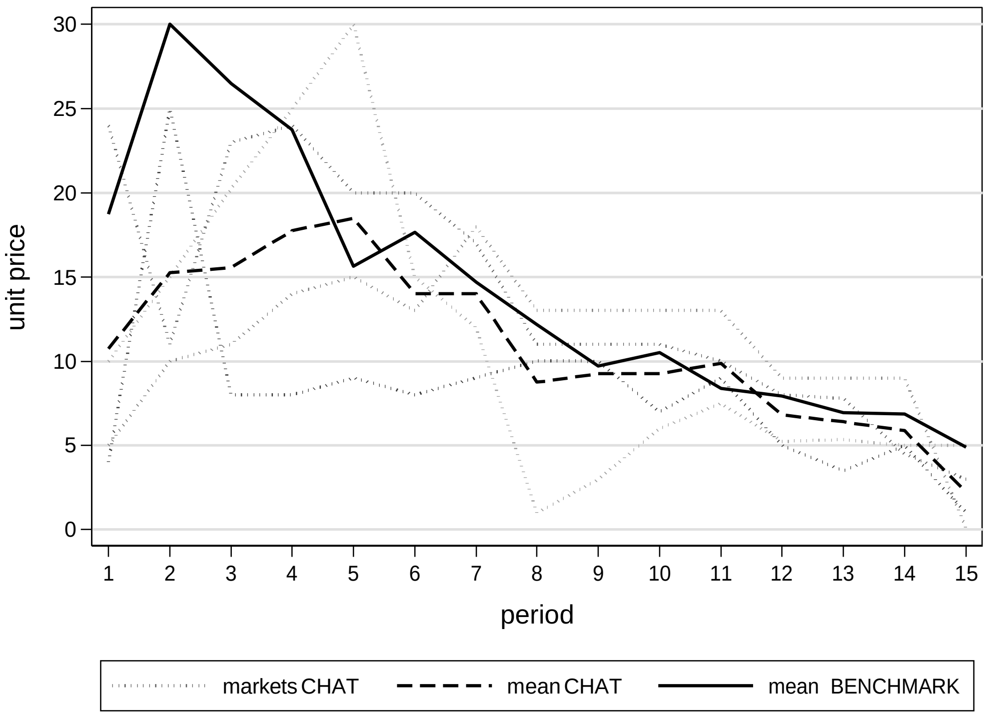
We analyze our data with respect to the treatment conditions, whereby we investigate price dynamics in the auctions and the secondary market, the distribution of income and the overall efficiency of the cap & trade system.

4.1 *CHAT*

Price dynamics

In *CHAT*, all agents of one market were allowed to communicate during the auction biddings and the trading in the secondary market. We first evaluate price dynamics, which are illustrated in Figures 2 and 3. Recall that certificate prices should not exceed 11.25EC, i.e. the fair value given a Type A-1 project worth 100ECU. This benchmark applies for unit auction prices as well as market prices.

Figure 2. Unit auction prices in *CHAT*



Prices are decreasing over the course of the game for both *CHAT* and *BENCHMARK*. In the beginning, prices tend to exceed the fair value, whereas in the end they tend to fall below the fair value. While the pattern in price dynamics is similar in *CHAT* and *BENCHMARK* from period 5 onwards, there are substantial differences at the beginning of the game. In all markets of *CHAT*, a unit auction price below the average unit auction price of *BENCHMARK* emerges. Applying a Wilcoxon-Rank-Sum test for the first five periods gives significant differences, with z=1.868 and p=.0617.[5] This might hint at collusive behavior that breaks down quickly as the game proceeds. We test this hypothesis by evaluating the chat protocols documenting the communication within the first periods.

Market #1: a total of 26 messages sent, 54%(58%) within the first (five) periods

Practically all meaningful communication takes place in the very first period. One subject during the auction stage asks how many certificates the other subjects are grandfathered and all others answer truthfully. This adds new information to the game as the distribution of certificates is not provided in the instructions. Furthermore, one subject suggests distributing certificates "justly", which is not answered by the other subjects. In the secondary market stage of the first period, another subject asks whether any of them has succeeded in the auction and obtained some certificates. Two subjects reply that they were not successful and one subjects notes that she was granted one certificate. The same subject then asks again at what price certificates were granted in the auction, although no one answers. In the second period, one subject states that there is a discrepancy between supply and demand, which is the last message sent until period 8. From this point onwards, no meaningful conversation occurs; rather, subjects merely tend to complain about prices being too high.

In sum, chat communication leads to the revelation of some information, i.e. the distribution of certificates grandfathered. There is an attempt to establish a cooperative regime by suggesting to distribute certificates justly, which is not picked up by other agents and attempts to cooperate break down altogether after the second period.

Market #2: a total of 38 messages sent, 11% (13%) within the first (five) periods

In the first period, one subject asks about the appropriate price for a certificate, whereby three other subjects reply that they do not know. In period 5, one subject asks why everybody wants to sell off certificates, but does not receive an answer. No more communication takes place until period 8. Subsequently, a discussion evolves, in which the incentives for each agent (accumulate many certificates at minimal prices) are correctly identified. It is noted that lying might generate some advantage and distinctively the fair value of certificates conditional on the availability of a Type A-1 project is derived. Some subjects undertake the attempt to agree bilaterally on a trading price or ask about the remaining project endowment of other subjects. Again, there is no successful collusion that explains the lower prices within the first periods when compared to *BENCHMARK*. However, the general properties of the game and the optimal pricing are explicitly mentioned in the discussion during the second half of the game.

[5] If not mentioned otherwise, all tests are carried out treating one market as one observation only.

Market #3: a total of 10 messages sent, 0% (100%) within the first (five) periods

In the second period, one subject explicitly suggests that all agents should bid less as certificates would become cheaper for all of them. This attempt to collude is referred to in period 3 by another subject and these two subjects agree upon a certificate price of 6ECU, which is about half of the fair value. In the secondary market of period 3, these two subjects complain that the agreement was obviously not followed by anyone else. There is no further communication after period 3.

Overall, in this market the explicit attempt to collude supported by at least two subjects failed and thus no further communication indicating cooperation occurred.

Market #4: a total of 11 messages sent, 18% (18%) within the first (five) periods

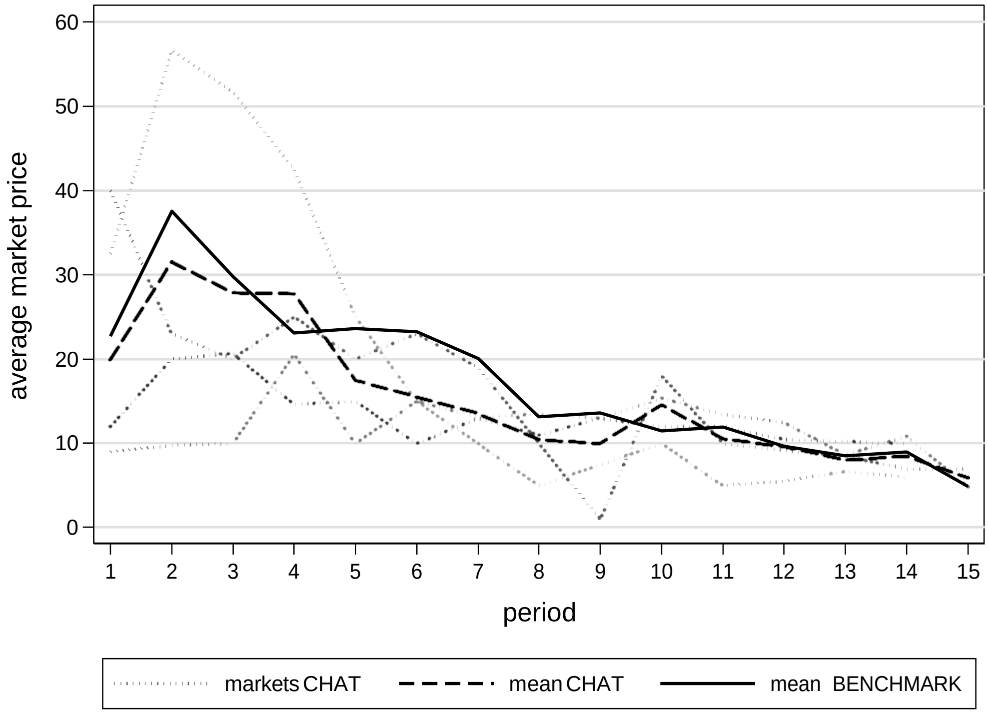
In this market, no meaningful messages are sent until period 13, when one subject notes that there will be a loss in income for the buyer at a price of 20ECU. Another subject states that it might make sense if one subject only misses out on one or two certificates, which is again answered by the first subject, who hints at the possibility to accumulate certificates over periods.

The few messages sent show no sign of cooperation or collusive behavior, which might explain lower unit auction prices when compared to *BENCHMARK*.

Result 1a: *Independent of chat communication among agents, prices tend to exceed fair values at the beginning before gradually decreasing below fair values at the end of the game. Chat communication leads to initially lower prices, which cannot be explained by collusive behavior.*

Considering average market prices, there is no such evident drop in prices when we allow for chat communication, as can be seen in figure 3.

Figure 3. Market prices in *CHAT*



As previous studies have emphasized (Meub et al., 2014, 2015, 2016; Proeger et al., 2015), average market prices tend to exceed unit auction prices, which might be explained by the endowment effect (Kahneman et al., 1991).[6]

Result 1b: *Average market prices decrease over the course of the game and tend to exceed unit auction prices independent of the possibility to communicate.*

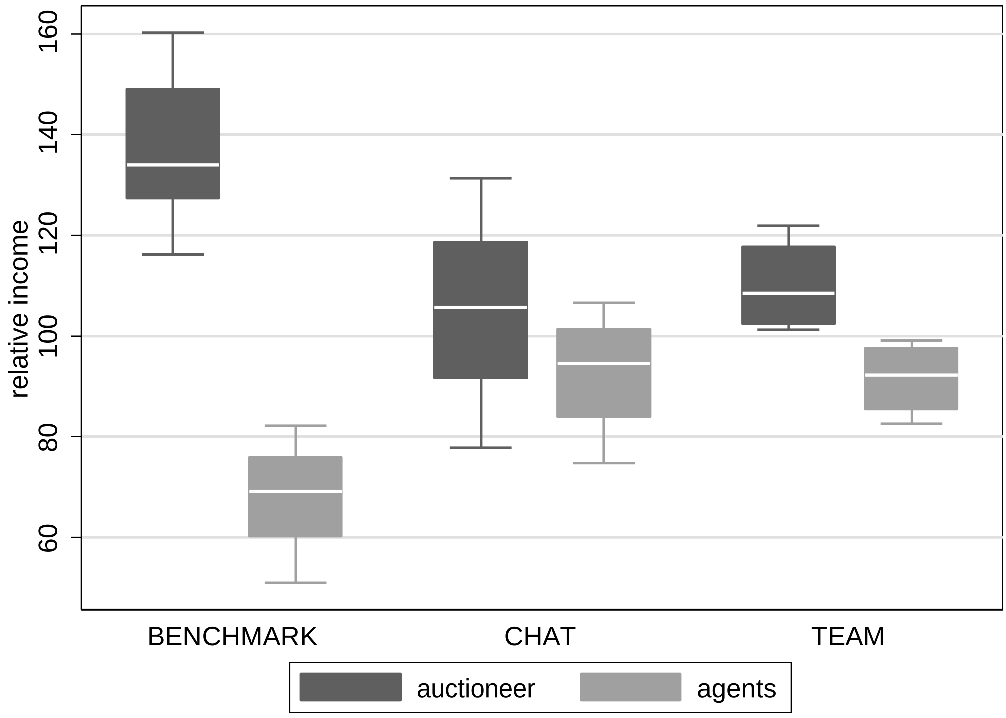
Distribution of income

While the distribution of income between the auctioneer and the market participants is not relevant for assessing the efficiency of a cap & trade regulation, the general political feasibility might well be influenced by the expected distributional effects.

Figure 4 illustrates the distribution of income between the auctioneer and the agents in the markets of *CHAT*. For a better comparability of income levels, we rely on aggregate income relative to the theoretical values derived above. A society's income is given by its aggregate value of realized projects, whereas the auctioneer's income is given by total payments made in the auction stage over the course of the game.

[6] Following our test for unit auction prices within the first five periods and applying a Wilcoxon-Rank-Sum test we find no significant differences with z=0.679 and p=.4969. For a more detailed analysis of the endowment effect in this TDR scheme, we refer to Meub et al., 2016.

Figure 4. Distribution of income between auctioneer and agents by treatment



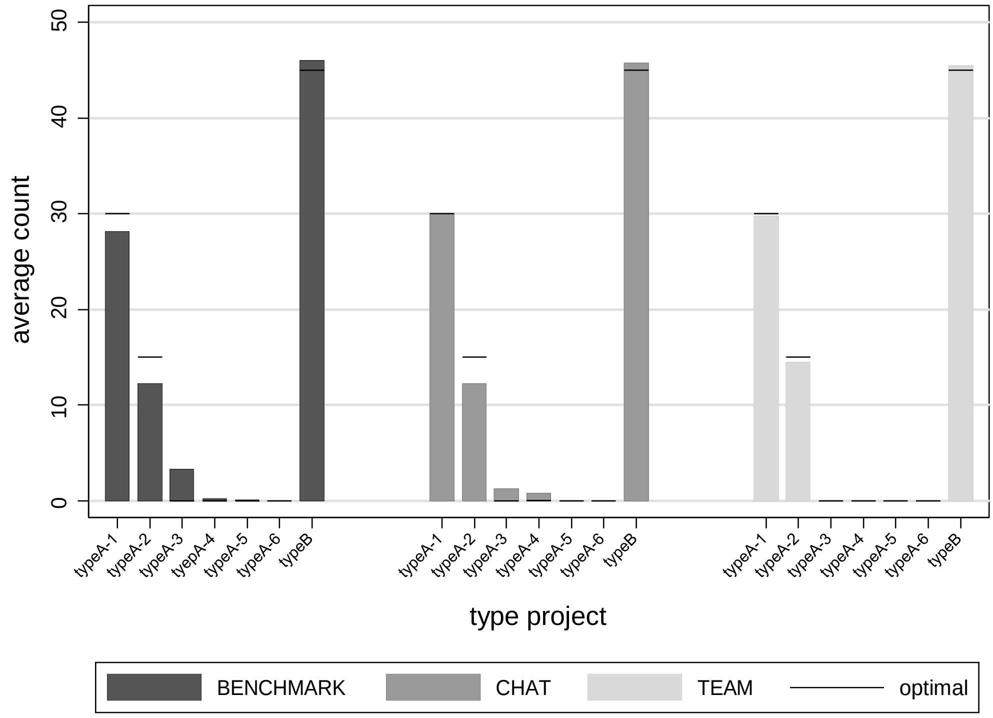
The boxplots clearly indicate a substantial discrepancy in relative income between the auctioneer and the market participants for *BENCHMARK*. By contrast, no such substantial difference occurs in *CHAT*. This pattern follows from higher auction prices in *BENCHMARK*, particularly at the beginning of the game

Result 1c: *In the absence of chat communication, overshooting unit auction prices induces a substantial redistribution of income in favor of the auctioneer.*

Efficiency of the cap & trade system

Recall that the cap & trade system's efficiency is measured by the aggregate value of realized projects. Certificates should optimally be reallocated such that the maximal aggregate value is achieved. Figure 5 depicts the average number of realized projects types by treatment condition.

Figure 5. Average number of project realizations by treatment



Comparing *BENCHMARK* and *CHAT*, there are no substantial differences. On average, societies in *BENCHMARK* reach 95.9% of the maximal aggregate project value, whereas in *CHAT* the degree of efficiency amounts to 97.7% on average. In both treatments, the expected pattern of about 30 Type A-1, 15 Type A-2 and 45 Type B projects evolves.

Result 1d: *The cap & trade system achieves high degrees of efficiency in regulating land consumption. Enabling agents to communicate does not change the expected pattern of realized projects and the overall efficiency remains high.*

4.2. *TEAM*

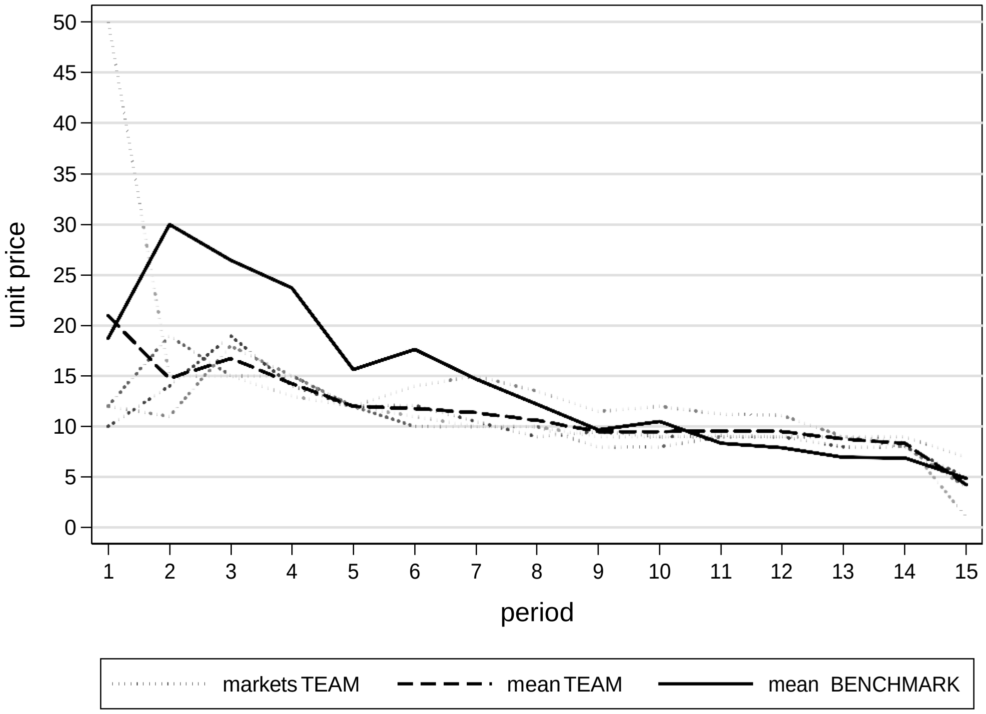
Price dynamics

Figures 6 and 7 illustrate price dynamics in the auctions and the secondary market for *TEAM* markets. Again, keep in mind that the fair value of one certificate amounts to 11.25ECU and there should be no differences across treatments.

We find the same basic pattern of decreasing unit auction prices throughout the game. Applying a Wilcoxon-Signed-Rank test gives significant differences in prices between the first and second half of the game (for *BENCHMARK* z=2.521 and p=.0117; for *TEAM* z=1.826 and p=.0679). However, aside from a single outlier in the very first period, unit auction prices in *TEAM* are substantially lower and the decline over the course of the game is much weaker.[7] Auction prices are quite homogenous across the markets of *TEAM* and prices are closer to fair values.

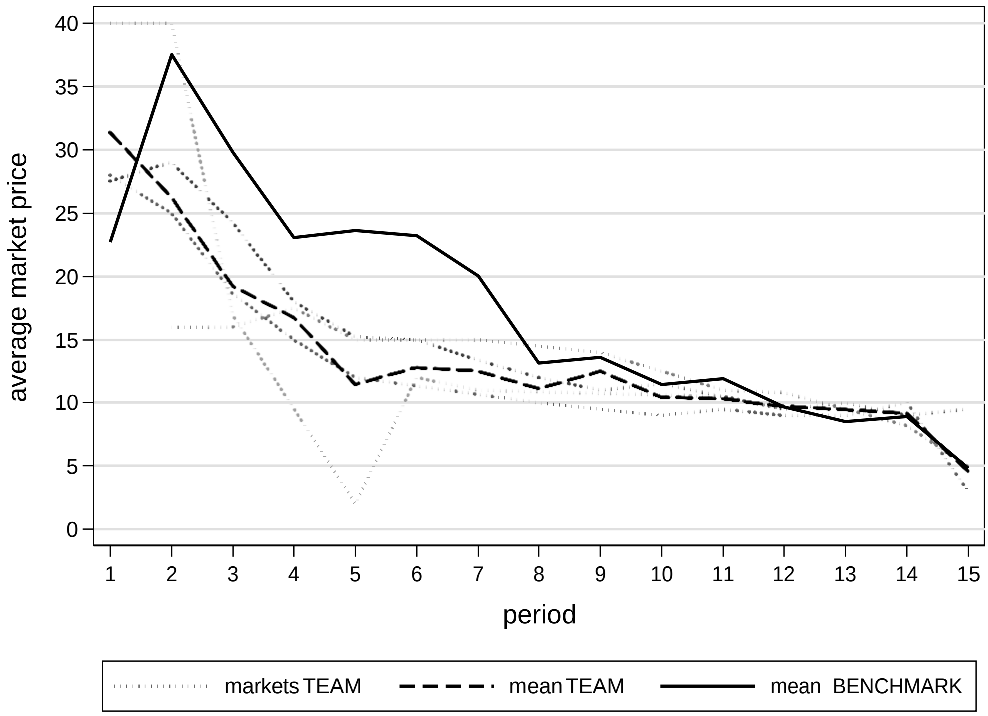
Result 2a: *Team decision-making brings unit auction prices closer to theoretically fair certificate prices. Thereby, price differences between the beginning and end of the game become much weaker as prices show high stability throughout the game across markets.*

Figure 6. Unit auction prices in *TEAM*



[7] For *BENCHMARK*, the average market price in the first (second) half of the game amounts to 27.28 (9.70), in Team the average amounts to 18.95 (9.97).

Figure 7. Market prices in *TEAM*



When considering prices in the secondary markets, we find that average market prices are lower in *TEAM* in the first half of the game when compared to *BENCHMARK* and they more rapidly approach the fair certificate value (Wilcoxon-Rank-Sum test, for the first half of the game gives z=1.868 and p=.0617; for the second half of the game z=-0.340 and p=.7341). However, the initially overshooting prices are not completely avoided when decisions are taken in teams.

Result 2b: *Team decision-making brings market prices closer to theoretically fair certificate prices, particularly in the first half of the game. Nonetheless, in the first third of the game, average market price still substantially exceed fair values.*

Distribution of income

As illustrated by figure 4, team decision-making decreases the auctioneer's income as unit auction prices are substantially lower and closer to fair values. The income distribution closely follows the theoretical predictions.

Result 2c: *Introducing team decision-making shifts the distribution of income in favor of the market participants as unit auction prices are substantially lower. The auctioneer realizes substantially less income.*

Efficiency of the cap & trade system

Figure 5 shows the distribution of projects realized on average for all treatments. The pattern of project realizations in *TEAM* evidently replicates the optimal distribution derived above. Almost 30 Type A-1, 15 Type A-2 and 45 Type B projects are realized on average. This finding should be interpreted as strong evidence in support of the assumption that team decision-making increases rationality, overcomes cognitive limitations and consequently results in a superior efficiency of the cap & trade system overall. Comparing the average relative efficiency of 99.0% achieved in *TEAM* to the 95.9% in *BENCHMARK* supports this conclusion (Wilcoxon-Rank-Sum test gives z=-2.727 and p=.0064).

Result 2d: *Introducing team decision-making leads to a more efficient reallocation of certificates as the distribution of realized projects is close to optimal across markets. Overall, when compared to individual decision-making, the cap & trade system shows superior efficiency if agents are represented by teams.*

5. Conclusion

This study presents experimental evidence on the feasibility of a system of TDR. We suggest that behavioral evidence can fruitfully complement previous qualitative and quantitative surveys as well as theoretical studies on the success factors of TDR schemes. While this approach adds novel evidence from counterfactual analyses to the discussion of optimal policy designs to reduce urban sprawl and foster sustainable land use, it has certain limitations. For instance, laboratory studies require a number of assumptions and restrictions to enhance their comprehensibility to participants and provide benchmarks of rational decision-making, thus reducing the extent to which real-world complexity can be implemented in experimental designs. Furthermore, student participants might act differently from decision-makers in the respective institutions. These aspects necessarily limit the direct transferability of our results. Despite these restrictions, we suggest that our counterfactual analysis on the effects of communication provides novel evidence unattainable by case studies. We extend previous experimental studies by relaxing the assumption of autonomous individual decision-making, which has constituted a strong deviation from the actual process of decision-making faced by agents in actual TDR schemes. By contrast, they are very likely to participate in networks and collaborate with other persons within their institutions when engaging in auctions and trading land use certificates.

We find that communication within teams making decisions in the TDR system reduces auction and market prices. Teams perform closer to game-theoretical predictions, which resonates with previous results in economic group research (Kugler et al., 2012, Charness and Sutter, 2012). This shifts the distribution of income in favor of market participants, thereby reducing the auctioneer's income. The efficiency of the cap & trade system substantially improves when decisions are made by teams rather than individuals.

While there is no equivalent improvement in overall efficiency when competitors within a market are allowed to communicate, we find that auction prices are similarly lower and thus closer to fair values. The same holds true for secondary market prices. Nevertheless, no collusion occurs. This result somewhat contradicts previous theoretical approaches emphasizing the likely problems posed by collusion; apparently, the structure of a TDR scheme impedes price arrangements among subjects. We find that competitors communicating via chat reveal additional information that is not available to subjects deciding autonomously. This enables subjects to make better informed decisions and presumably benefits, which particularly applies for subjects with a limited understanding of the system and cognitive limitations. Hence, biddings in the auctions and trades in the secondary market reflect fair prices more appropriately. In short, allowing subjects - even when competing - to communicate in a TDR system reveals some information, and - similar to the process of a group discussion within teams – more information leads to better decisions.

Consequently, as communication tends to reveal information and improve subjects' understanding of the cap & trade system's working mechanism, TDR function equally or even more efficiently in comparison to a situation of autonomous individual decision-making. Certificates are reallocated almost optimally, enabling the realization of the most profitable projects. From a policy perspective, these results mitigate previous doubts about the feasibility of TDR schemes due to irrationally overshooting prices in both auctions and secondary markets. Subjects' ability to improve their understanding and learn when enabled to communicate thus precludes an overly strong redistribution of income in favor of the auctioneer, which would substantially hamper its political feasibility. Concerns about collusive behavior manipulating prices might similarly be less problematic as no price arrangements to the disadvantage of the auctioneer are realized. In sum, doubts about the feasibility of a TDR scheme due to participants' non-optimal or strategic behavior combined with the system's susceptibility to price manipulations appear less problematic.

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Appendix: Instructions for the *BENCHMARK* treatment. The differences for *CHAT/TEAM* are indicated in braces.

OVERVIEW OF THE GAME

You can earn money in this game by realizing projects and trade with certificates. At the beginning, you will be randomly assigned to a group of 6 players, which will remain constant during the 15 periods of the game. {*CHAT*: You can communicate with these players using a chat box during the game. *TEAM*: Further, you have a teammate, with whom you will have to take your decisions.} All prices and values in the game will be paid in ECU with up to two positions after decimal point. 100 ECU convert to 1€ for your payoff. {*TEAM*: Your gains from the game will fully be paid to each of the two players.}

Projects

Overall, each player has 30 projects of **Type A** and 15 projects of **Type B**. Both types of projects have different values, which are shown in this table:

Type of project	Project value (in ECU)
A	0 to 100
B	10

In each period, only one project can be realized. Before the game starts, the values of all Type A projects will be assigned and shown to you. All players are assigned different Type A projects.

Certificates

For the realization of Type A projects, you need 8 certificates each, Type B projects do not require certificates. Certificates are assigned to you at the beginning of each period and auctioned. Additionally, certificates can be traded among the players. In the game, you receive an endowment of 700 ECU which you can use to buy certificates at the auction and from the other players. You can also sell certificates and thus increase your payoff.

Your payoff

The payoffs you receive in the course of the game, as well as the sum of all realized projects add up to your final payoff. Further, a basic payoff of 400 ECU will be added.

COURSE OF THE GAME

Each of the 15 periods follows an identical course, which consists of three phases.

Phase 1: Allocation and auctioning of certificates

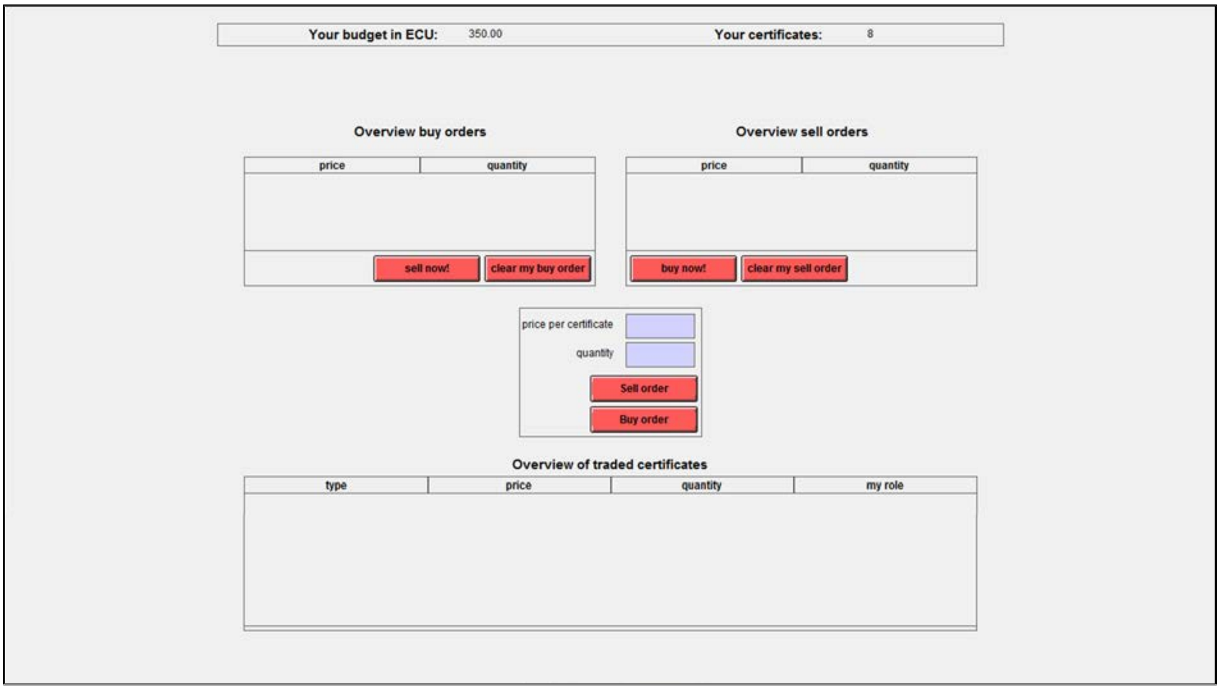
At the beginning of each period, 12 certificates are allocated. The number of certificates a player receives is determined randomly at the beginning of the game and does not change during the game.

Additionally, after the allocation, 12 certificates are auctioned. Depending on your current funds, you can bid for a number of certificates of your choosing at a unitary price. The 12 highest bids will receive the certificates to the price of the lowest successful bid.

Phase 2: Trading of certificates

Following the allocation and auctioning, this phase lets you trade with the other five players, i.e. buy and sell certificates. You can offer a trade yourself and also accept offers from other players. To clarify this, you see the respective screen of the trading phase below:

{Translated screenshot for *BENCHMARK / TEAM*:}



{Translated screenshot for *CHAT*:}

Offering a trade

In the {BENCHMARK/*TEAM*: lower} {*CHAT*: left-hand mid-level box} box, you can enter a price (in ECU) and the respective amount of certificates that you would like to buy.

- **By clicking "searching"**, all players are shown your buying desire in the {BENCHMARK/*TEAM*: left} {*CHAT*: upper}box. Once another player agrees to your offer, you will receive the respective number of certificates. The total value (price x quantity) of the trade will be withdrawn from your funds.
- **By clicking "offering"**, all players are shown your sell offer in the {*CHAT*: upper} box {BENCHMARK/*TEAM*: on the right}. Once another player accepts your offer, you sell the respective number of certificates. The total value (price x quantity) of the trade will be added to your funds.

Accepting another player's offer

In the boxes on the {*CHAT*: upper}right and left side, you can see all current buy and sell offers for certificates. If you choose an offer and click on "sell now!" or "buy now!", you make the trade with the respective player.

You are allowed to trade as often as you please. You can also make multiple sell and buy offers at the same time. The trading phase ends automatically once **2 minutes** have passed.

Phase 3: Realizing projects

In the third phase of the game, you can realize one of your projects. You will receive the respective payoffs (project value in ECU) at the end of the game. After the third phase, the next period begins. Certificates that are not used in one period can be saved for subsequent periods. Note, however, that you will not receive a payoff for certificates that remain unused until the end of period 15!