UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

Optimal support for renewable deployment: A case study in German photovoltaic

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Cambridge, 14.05.10

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Outline

1. **Solar energy is an option**
2. Technology learning as a random walk
3. The German policy
4. A simple model for solar learning
5. Feed-in policy as an optimal-stopping problem
6. Conclusion

Fed up?

The Economist

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Germany's solar subsidies

Fed up

Germany's support for solar power is becoming ever harder to afford

Jan 7th 2010 | BERLIN | From *The Economist* print edition

It's raining solar panels

AFP

January 7, 2010

The economics of solar energy

- Photovoltaic energy is still 3 to 12 times more expensive than onshore wind
- But in Germany, every installed panel is a profitable investment due to a generous feed-in tariff (guaranteed pay-back)
- Germany attracted half the world's installation, last year

Solar energy is an option

The question is not: will solar energy be economical by 2020, or not?

But rather: should we explore the option of solar energy, for one more year?

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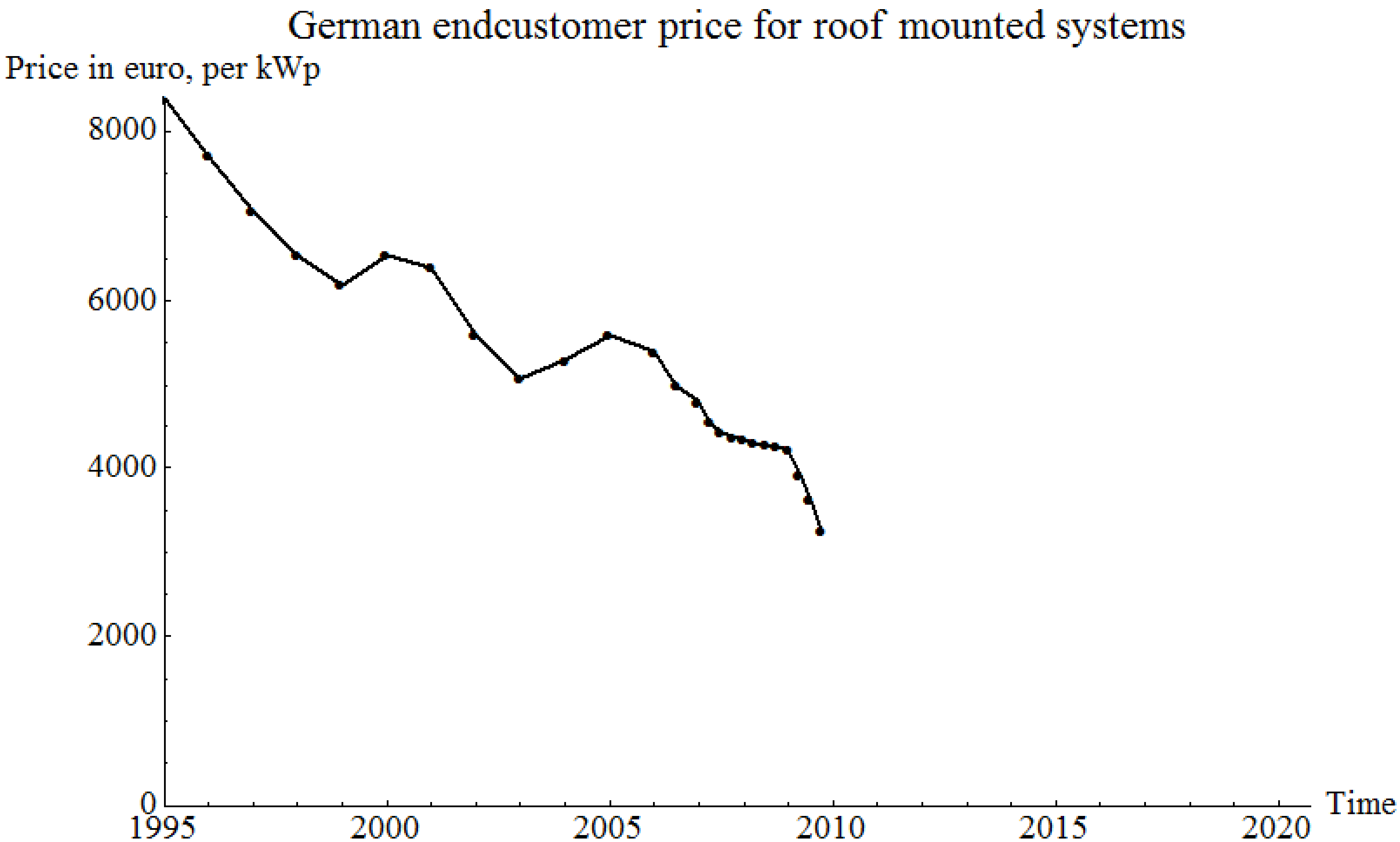
How fast is fast enough?



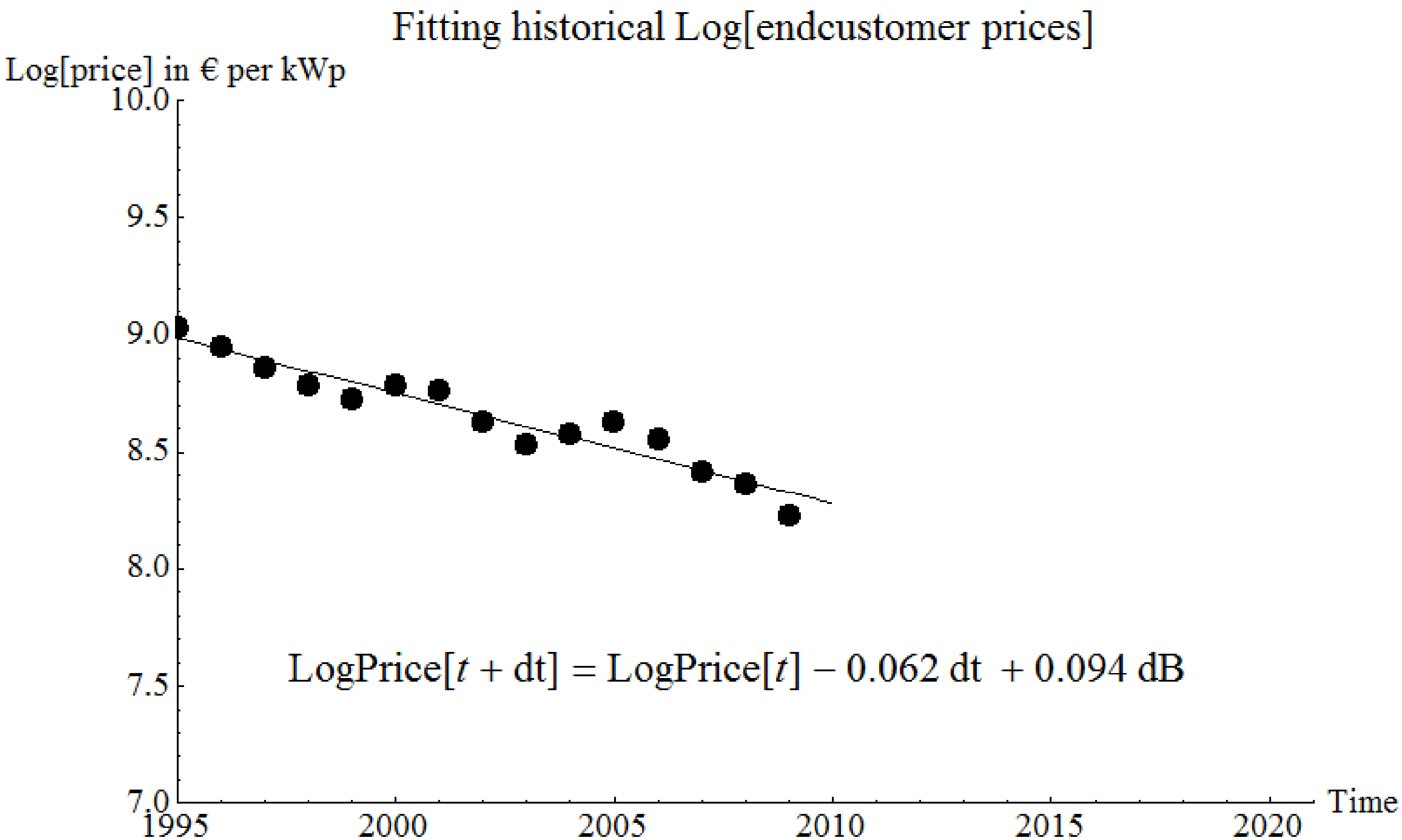
Sources:
1) National Survey Report of PV Power Applications in Germany 2008, Version 2, Lothar Wissing, Forschungszentrum Jülich, May 2009
2) Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik), Bundesverband Solarwirtschaft, Nov 2009

Moore learning

"The performance of processors has increased at a rate of roughly a factor of two per year. Certainly over the short term this rate can be expected to continue."

Intel co-founder, Gordon E. Moore, 1965

Learning: a random walk?



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German EEG law for 2010

The tariff paid for electricity from installations generating electricity from solar radiation shall amount to **31.94 cents per kilowatt-hour**.

The tariff paid for electricity from installations generating electricity from solar radiation which are exclusively attached to or on **top of a building** [...] shall amount to **43.01 cents per kilowatt-hour** [...].

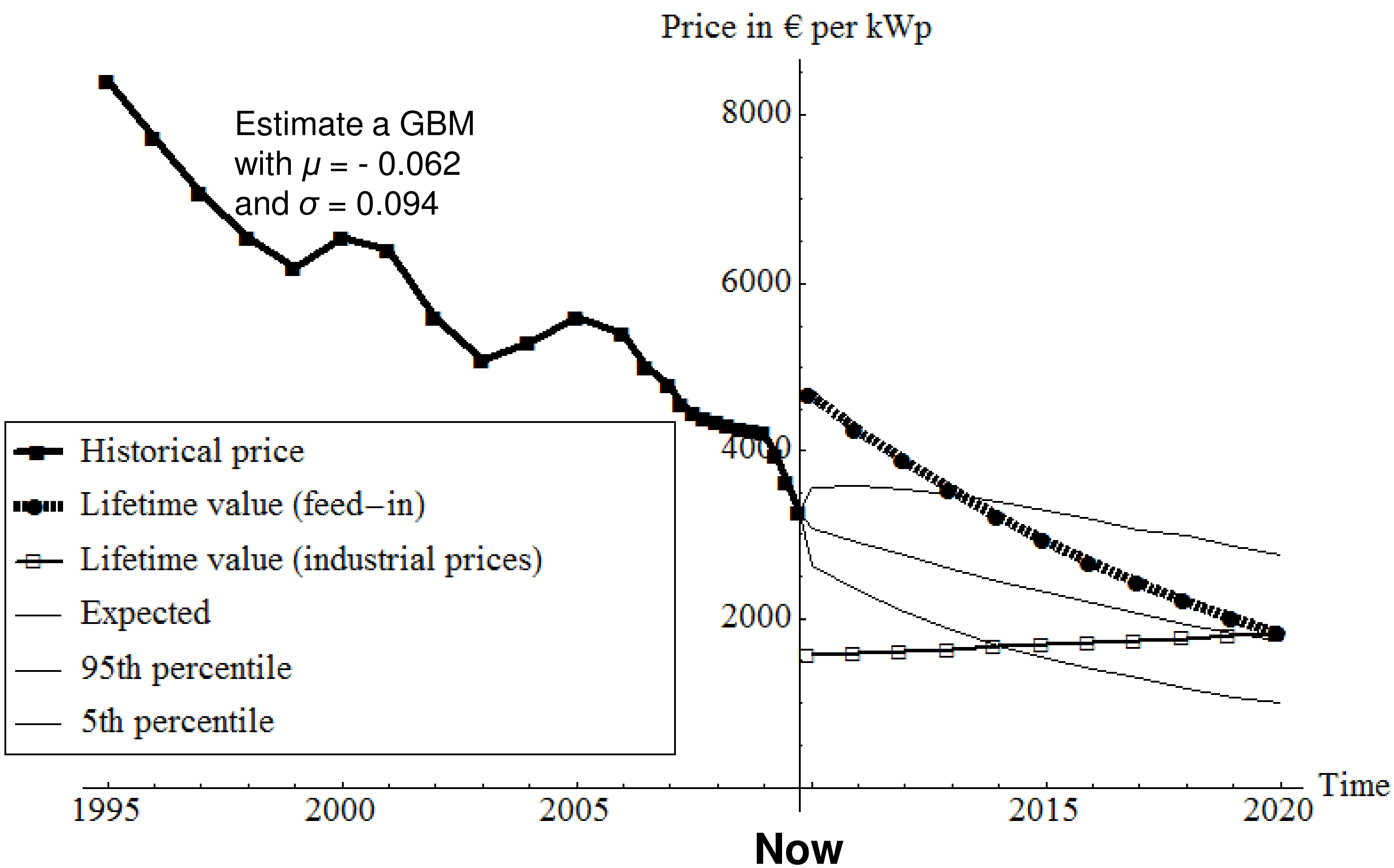
English and German versions available on
http://www.erneuerbare-energien.de/inhalt/42934/40508/

And onwards!

The annual percentage **degression** for tariffs [...] for electricity generated from solar radiation [...]
a) shall be **10.0 per cent** in the year 2010
b) shall be **9.0 per cent** from the year 2011 **onwards**

English and German versions available on
http://www.erneuerbare-energien.de/inhalt/42934/40508/

Will it reach the target in 2020?



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A simple model for solar learning

Start in 2010

1. Government announces the **feed-in tariff** for years to come

tariff -€

2. The consumer decides if it is profitable to buy & install solar panels

3. If yes, total capacity grows at the maximum rate

3. If not, new deployment halts

+€

4. Developer runs down the **stochastic** learning curve

5. Developer of solar panels quotes **new** price for yr X

What is in it for the government?

The government is in it for the long run, and

"Eternity is very long, especially towards the end." Woody Allen

The combination of a fixed growth rate AND an infinite time-horizon can never lead to a sensible decision criterion

Reward upon commercialization

Suppose that every cent, that solar energy is cheaper than €0.16/kWh, by 2020, leads to **€40 billion of savings nationwide**, after 2020

To recover the total cost of the program (~€80 billion), the price of solar energy would have to drop to €0.02/kWh below €0.16/kWh

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How the government really decides

ZEIT ONLINE | WIRTSCHAFT

SONNENENERGIE

Feilschen um jeden Cent

Der Streit um die Höhe der Förderung von Solarstrom spaltet die Republik. Jetzt beginnt der Entscheidungsprozess im Parlament.

© Sean Gallup/Getty Images

Ein Besucher im Solarpark Lieberose in Brandenburg, Unternehmensangaben zufolge der größte Solarpark Deutschlands

26 March, 2010

Model assumptions

1. **Government**
   - Announces future tariffs
   - Running costs depend on the tariff only
   - The target is €0.16/kWh by 2020
   - If the target is reached, savings are realized
2. **Market**
   - If the market cannot beat the tariff, it doesn't grow
   - If the market can beat the tariff, it grows at an exogenous, constant rate
3. **Stochastic learning**
   - The dependence on the growth rate is deterministic
   - But it has a random component as well

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Trouble ahead

"Beyond numerical results, very little is known about most [...] options which expire in finite time."

New Palgrave Dictionary of Economics, Ross (1987)

See e.g. Dixit & Pindyck: Investment under Uncertainty

New procedure!

1. **We can value policies analytically**
   - Normally one would run a simulation
   - The value is expressed as an infinite sum

2. **We can optimize over the policy**
   - For optimization, a miracle occurs and it turns out that the infinite sum collapses
   - We get a Volterra equation of the 2nd kind
   - Known numerical procedures can be applied

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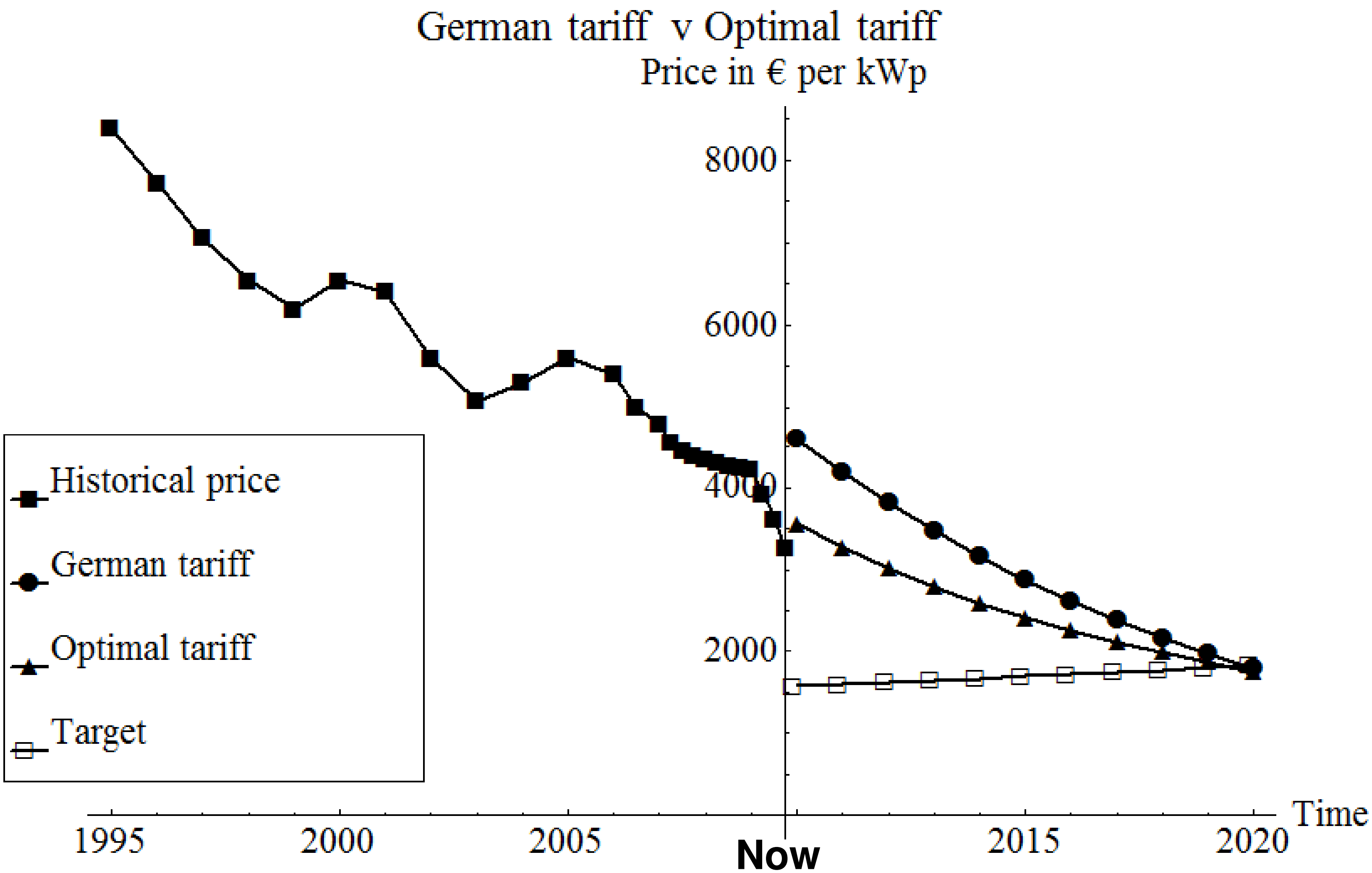
German v Optimal tariff



German v Optimal tariff

Year	German	Optimal
2010	€0.43/kWh	€0.32/kWh
2011	9%	8%
2012	9%	8%
2013	9%	7%
2014	9%	7%
2015	9%	7%
2016	9%	6%
2017	9%	6%
2018	9%	6%
2019	9%	6%
2020	9%	6%

Model assumptions

1. **Government**
   - Announces future tariffs
   - Running costs depend on the tariff only
   - Solar energy should beats €0.16/kWh by 2020
   - If the target is reached, savings are realized
2. **Market**
   - If the market cannot beat the tariff, it doesn't grow
   - If the market can beat the tariff, it grows at a rate is an exogenously given function of time
3. **Stochastic learning**
   - The dependence on the growth rate is deterministic
   - But it has a random component as well

Conclusions

This work contributes

1. Theoretically
   - by showing that one can use (rather complicated) formulae, rather than simulations, to value options
   - by extracting new optimality conditions from these formulae
2. Hopefully practically
   - by formulating technology-learning problems as optimal-stopping problems

Appendix: parameter assumptions

Consumer discounts future cash flows **5%** p.a.	**German weather** average solar output is **10%** of peak
Market growth Growth equals **15% until 2020** as long as the price of solar stays below the threshold	**Stochastic learning curve** The process is driven by a geometric Brownian motion with $\boldsymbol{\mu = -0.062}$ and $\boldsymbol{\sigma = 0.094}$
Energy prices Domestic and industrial energy prices grow by **2%** p.a.	**Time horizon** the aim is that solar energy has a price of less than **€0.16/kWh** by **2020**
Running costs Determined by the tariff **(decision variable)** and the yearly growth-rate	**Realized savings** **€40billion** in savings are made for every cent that solar energy costs less than €0.16/kWh, by 2020