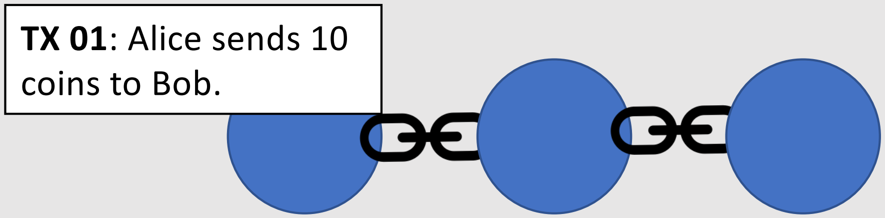
Dynamic Posted-Price Mechanisms for the Blockchain Transaction-Fee Market

Matheus V. X. Ferreira, Daniel J. Moroz, David C. Parkes, Mitchell Stern

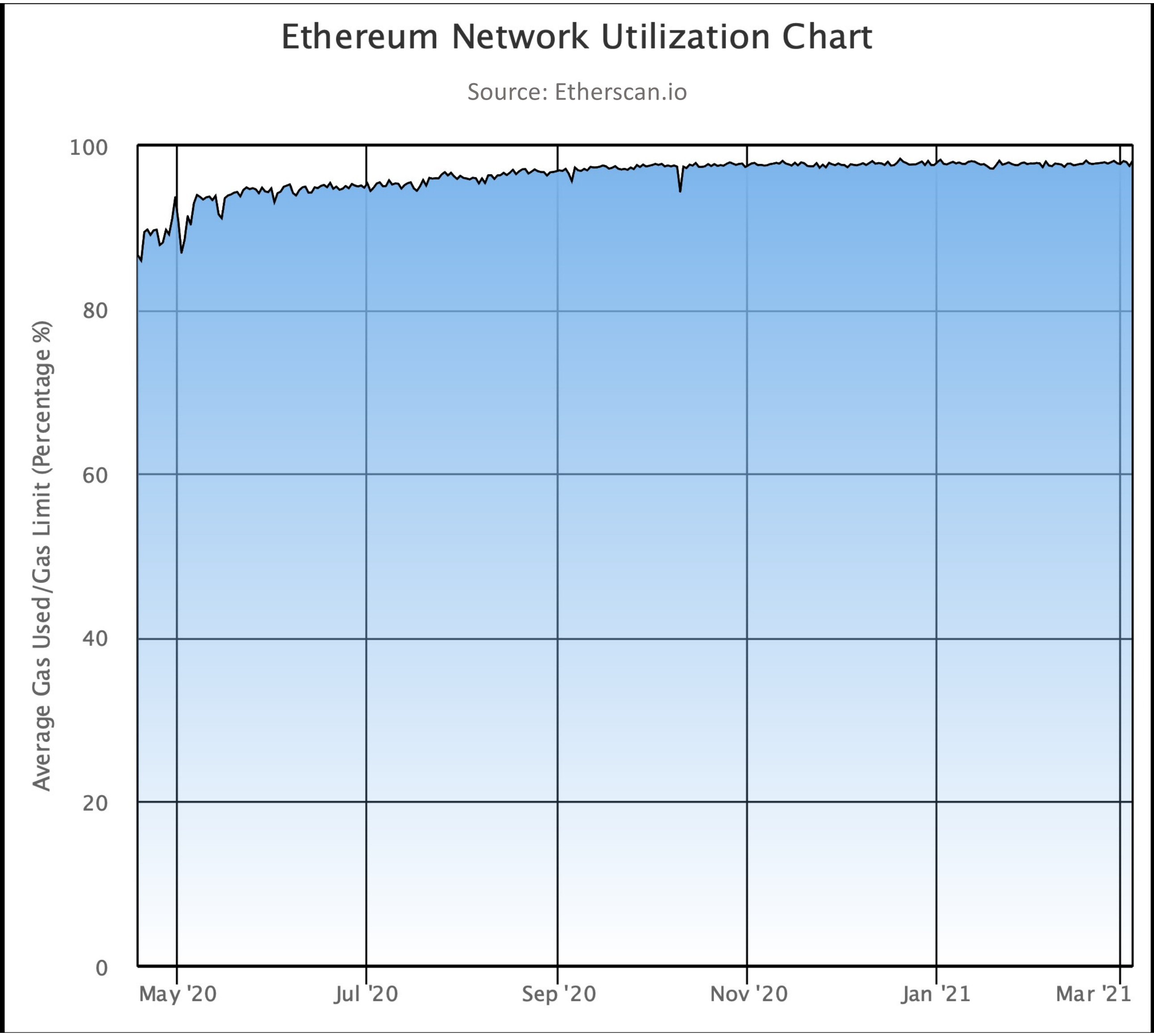
Blockchains

Distributed ledger of transactions.

- Managed by a **decentralized** network of miners.



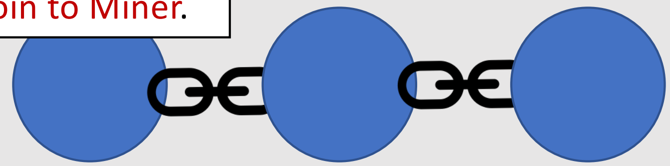
Pending Transactions			
TX ID	Sender	Receiver	Value
01	**Alice**	**Bob**	**10**
02	Charlie	David	15
03	Bob	Charlie	1


Ethereum Network Utilization Chart
Source: Etherscan.io
Average Gas Used/Gas Limit (Percentage %)
100
80
60
40
20
0
May '20
Jul '20
Sep '20
Nov '20
Jan '21
Mar '21

Transaction fee Mechanism

[Nakamoto '08] To select transactions, miners implement a first-price auction to select transactions.

TX 01: Alice sends 10 coins to Bob and 1 coin to Miner.



Pending Transactions				
TX ID	Sender	Receiver	Value	Tip
01	**Alice**	**Bob**	**10**	**1**
02	Charlie	David	15	0.01
03	Bob	Charlie	1	0.5

Estimated fee

Segwit

0.00001869 BTC

$ 0.56

For confirmation within 2 blocks

~ 20 minutes

Inputs 1

Outputs 2

Total amount of bytes: 222

A fee rate of **8.417** Satoshi/byte applies for confirmation within the next **2** blocks.

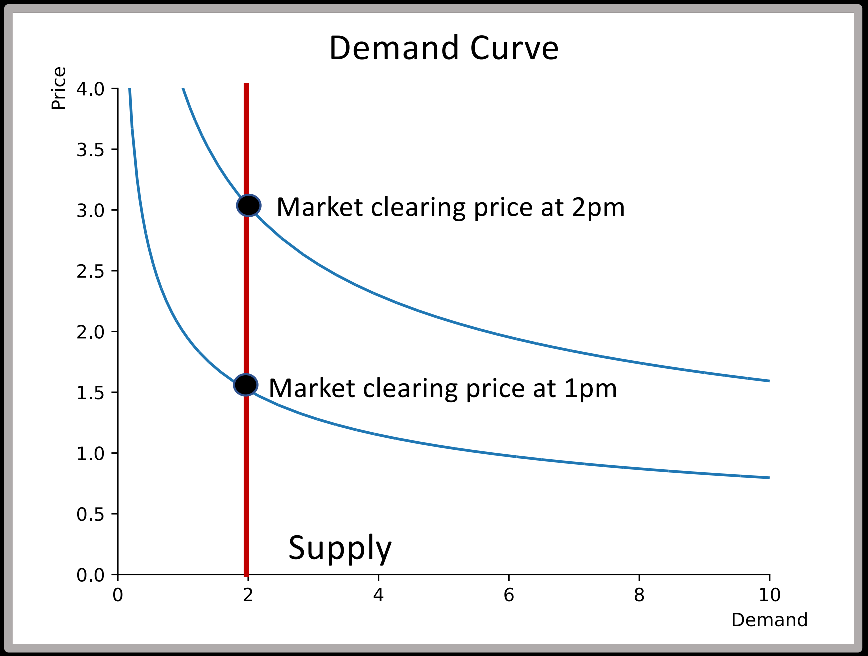
Source: https://btc.network/estimate

Accessed: 9/23/2021

Posted-price provides simplicity

Research Question

- How to dynamically price block space given future demand is unknown?

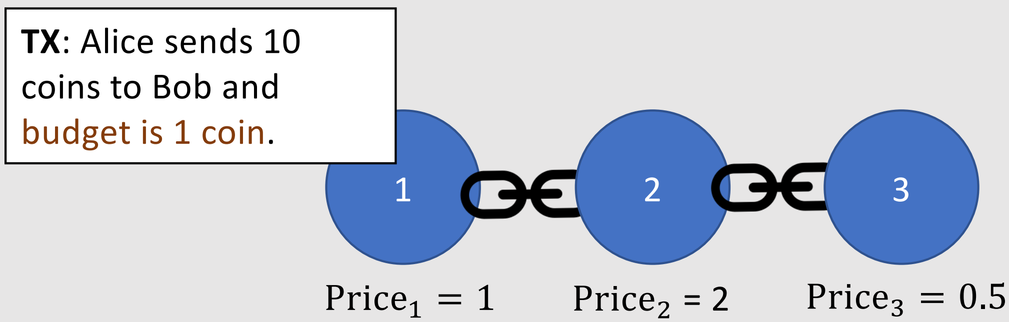


Approach

1. Each block contains a posted-price: $Price_t$.
2. Miner can **ONLY** include transactions with a budget above $Price_t$.
3. Bidder pays $Price_t$.
4. Compute the posted-price for next block

Pending Transactions				
TX ID	Sender	Receiver	Value	**Budget**
01	**Alice**	**Bob**	**10**	**1**
02	Charlie	David	15	**0.01**
03	Bob	Charlie	1	**0.5**

Example: Dynamic Posted-Prices



Ethereum Improvement Proposal (EIP) 1559 [Buterin et al., ‘19]

- London hard fork (August 4th, 2021).

Pending Transactions					
TX ID	Sender	Receiver	Value	Tip	**Budget**
01	**Alice**	**Bob**	**10**	**0.01**	**1**
02	Charlie	David	15	0.01	**0.01**
03	Bob	Charlie	1	0.01	**0.5**

Pricing Rules

Utilization-based (EIP-1559)

Welfare-based

Truncated Welfare-based

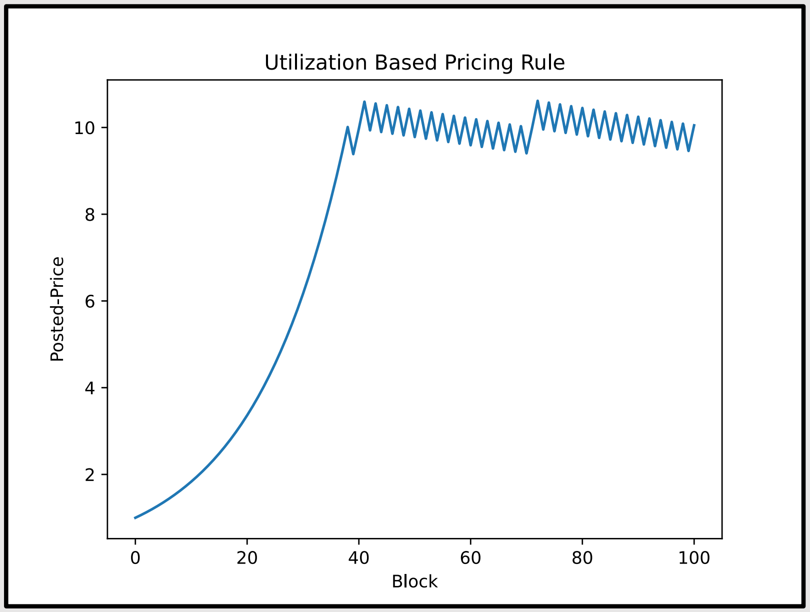
Utilization-based rule

$$Price_{t+1}^{U} = Price_{t}^{U}(1 + \alpha(Utilization - Target))$$

- Block $\boldsymbol{Utilization} = \frac{\#\, Transactions\ in\ Block}{Block\ Capacity}$.
- **Target** utilization ($Target = $ ½ in EIP-1559).

Instability of Utilization-based rule

- Consider 50 slots for sale and 100 users with value 10 (each round).



$$Price_{t+1} = Price_t(1 + \alpha(Utilization - \underbrace{\cancel{Target}}_{= 1/2}))$$

$$= Price_t\left(1 \mp \frac{\alpha}{2}\right)$$

Welfare-based pricing rule

$$\boldsymbol{Welfare(Block) = \sum_{i \in Block} v_i}$$

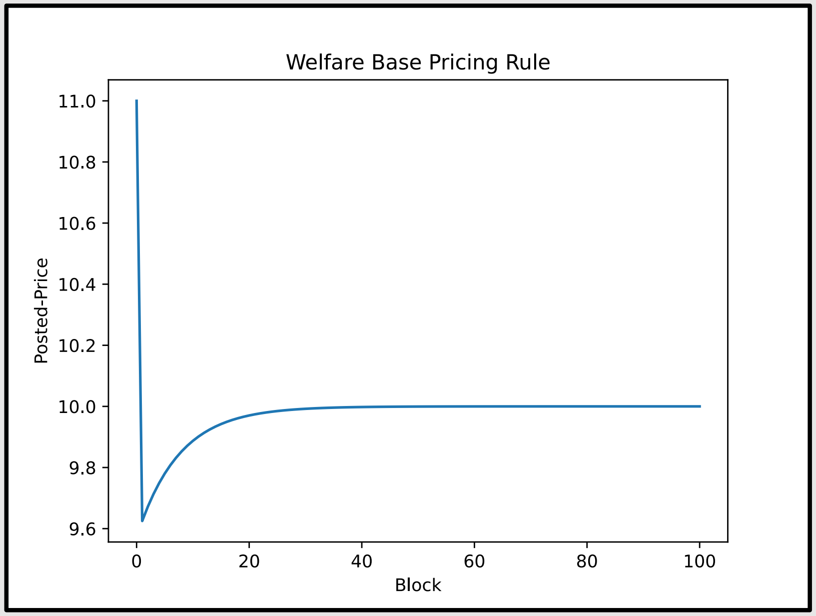
$$\mathrm{P}rice_{t+1}^{W} = \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t^W$$

- Each transaction contributes $\frac{\alpha v_i}{Capacity}$ (where v_i is the bid of bidder i).

Example: Welfare-based

- Consider 50 slots for sale and 100 users with value 10.
- Case 1 ($Price_t^W > 10$):

$$
\begin{aligned}
\mathrm{Price}_{t+1}^{W} &= \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t^W \\
&= (1-\alpha)Price_t^W \\
&< \mathrm{Price}_{\mathrm{t}}^{W}
\end{aligned}
$$



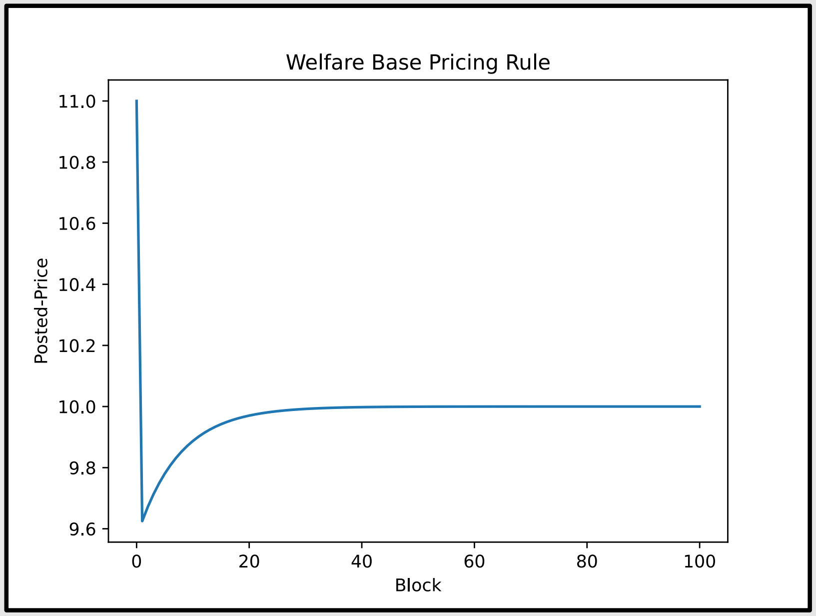
- The eventually $Price_{t+1}^W \leq 10$.

Example: Welfare-based

- Case 2 ($Price_t^W \leq 10$):

$$\begin{aligned} Price_{t+1}^W &= \alpha \frac{Welfare(Block)}{Capacity} + (1-\alpha)Price_t^W \\ &= 10\alpha + (1-\alpha)Price_t^W \\ &\geq Price_t^W \text{ and } \leq 10 \end{aligned}$$

- Thus, sequence of prices o monotone increasing.
- From monotone convergence, posted-price converge.



Quality of convergence?

If we had converged to a price > 10,
then the mechanism obtains zero welfare.

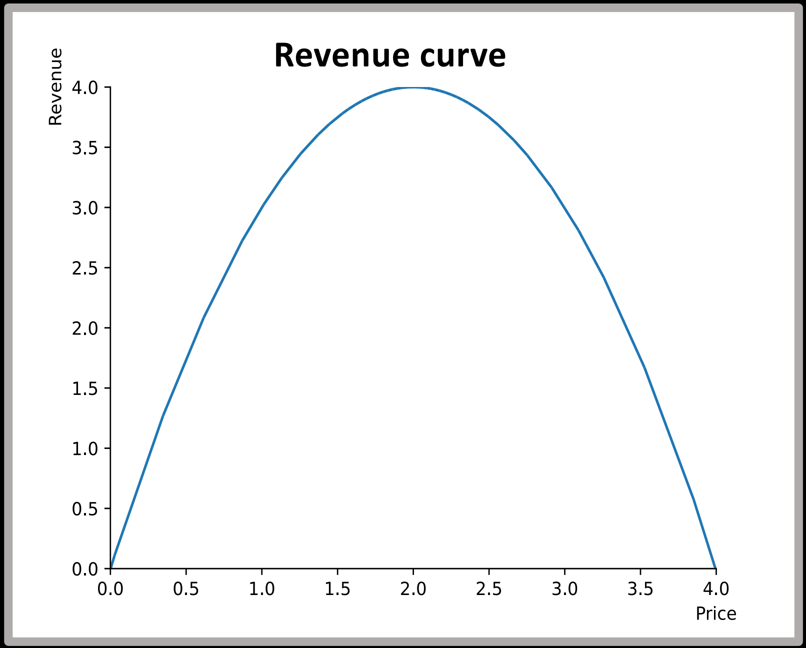
Main result 1: Welfare guarantees

[Theorem] Assume values are drawn i.i.d. Then the utilization-based, welfare-based and the truncated welfare-based obtain ¼ of the **optimal welfare** at equilibrium.

[**Optimal welfare**] Welfare obtained by selling at the market clearing price.

Main result 2: Convergence guarantees

- If the **revenue curve** is strict concave and Lipschitz continuous, there is an α such that the welfare-based and utilization-base rules are stable.

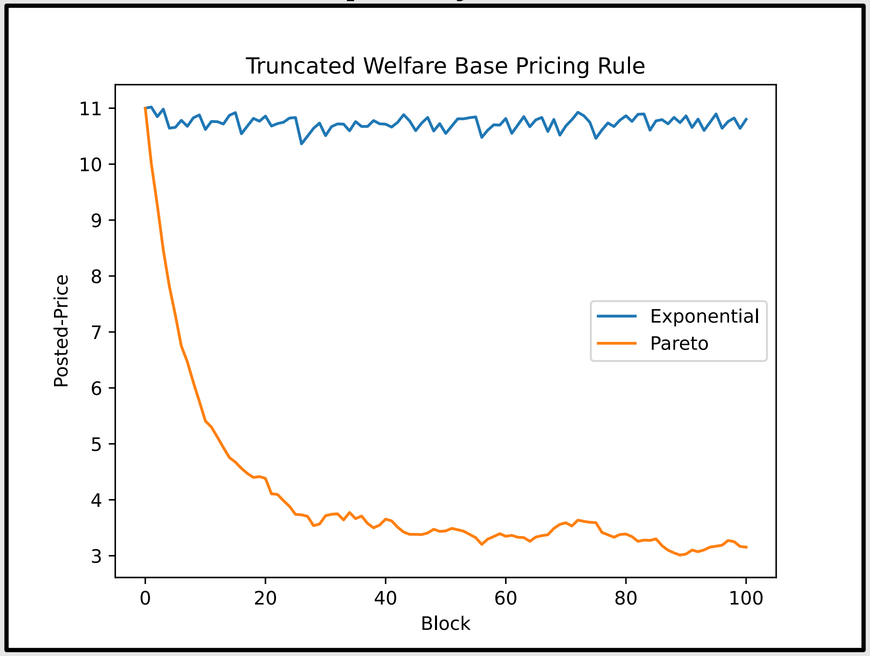


Improving the Welfare-base rule

Truncated Welfare-based rule

- Each transaction contributes $\frac{\alpha \min\{v_i,(1+\delta)p_i\}}{Capacity}$ to next price.

v_i is the bid of bidder i
p_i is the payment of bidder i



Conclusion

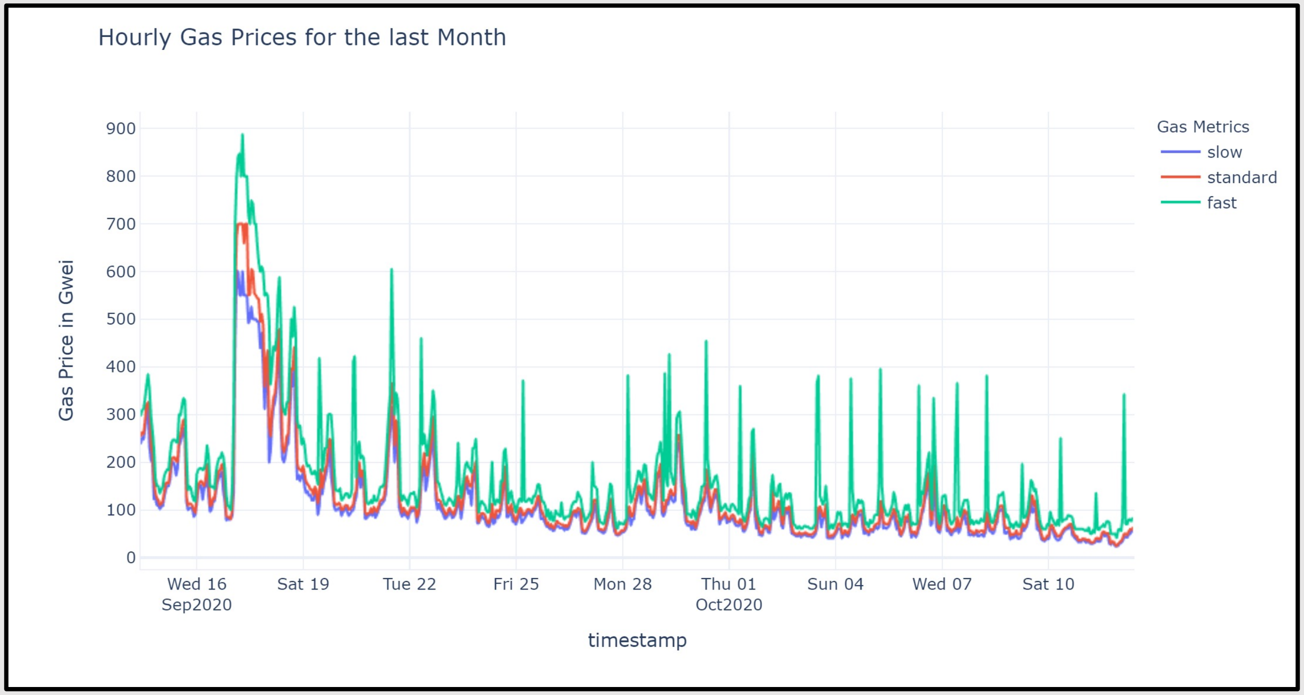
- Dynamic posted-prices provides predictable payments.
- We give conditions for the stability of pricing rules and welfare guarantees at equilibrium.
- Using observable bids (rather than block utilization) reduces price volatility and increases welfare.

Future direction: quantify a good pricing rules

- **Welfare**: quantifying the tradeoff between larger blocks and network delays.

- **Strategyproofness**: users might prefer to wait in exchange for lower payments.

Future direction: predict demand changes



Source: https://www.anyblockanalytics.com/blog/historical-ethereum-gas-price-analysis/


Thank you